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ARKANSAS-RED RIVER BASINS WATER QUALITY CONSERVATION. REPORT ON A BASIC STUDY OF WATER QUALITY, SOURCES OF NATURAL AND MANMADE SALT POLLUTION, AND SUGGESTED CORRECTIVE MEASURES

Public Health Service
Washington, D. C.

June 1964

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Arkansas-Red River Basins

WATER QUALITY CONSERVATION

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U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service

Arkansas-Red River Basins

WATER QUALITY CONSERVATION

Report on a Basic Study of Water Quality,
Sources of Natural and Manmade Salt Pollution,
and Suggested Corrective Measures

COLOR ILLUSTRATIONS REPRODUCED
IN BLACK AND WHITE

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
Washington, D.C. 20201

June 1964

Preface

The Arkansas and Red Rivers and their tributaries are one of the Nation's largest water resources and drain about 8 percent of the continental United States. These river basins encompass all of Oklahoma and parts of Colorado, New Mexico, Kansas, Texas, Missouri, Arkansas, and Louisiana.

The high mineral content of the Arkansas and Red Rivers and of some of their tributaries limits their use as sources of water supply for municipalities, industries, and agriculture. The mineral pollution of these streams results principally from both natural brine emissions and oil production activities.

The Arkansas-Red River Basins study, concentrating on abatement of natural and man-made brines, was begun in 1958, and represents the first step in the development of a comprehensive program to control water pollution. Preliminary evaluations of the available data and general scope of the problem were made in cooperation with numerous Federal, State, and local agencies. As a result, detailed basinwide studies were recommended to provide the basic information required to more fully define the problem and develop plans for quality improvement in these two great river basins.

In August 1959, Congress provided for the continuation of the study by approving funds for "* * * the Arkansas-Red River Water Quality Conservation Project" (*1*). Field investigations were conducted for 2 years to provide information for a basic report. Natural and man-made sources of salt pollution needed to be identified and described and proposals made for the reduction or elimination of natural salt discharges into the Arkansas-Red River system.

This report presents the major findings, conclusions, and recommendations of the study. Detailed discussions and supporting data are presented in a separate appendix comprising three volumes, which are available on request:

Volume I	The Mineral Pollution Problem and Proposed Solutions
Volume II	Benefits Evaluation
Volume III	Water Quality Data

The Senate Committee on Public Works, by resolution adopted December 16, 1959, requested the Board of Engineers for Rivers and Harbors to review former reports of the Chief of Engineers on the Arkansas and Red Rivers and their tributaries. The committee requested that this be done with a view to determining, in cooperation with the Division of Water Supply and Pollution Control, Public Health Service, methods and means of improving and managing water quality in these basins. A report by the U.S. Army (Corps of Engineers) is scheduled for release in two parts during fiscal year 1965.

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Introduction

Authority for Project

Investigations of salt pollution of the Arkansas and Red Rivers were undertaken by the Public Health Service as authorized by the Federal Water Pollution Control Act (33 U.S.C. 466 et seq.).

Purpose and Scope of Project

The objectives of the project were:

1. To locate and define the significant natural and manmade sources of salt (mineral) pollution.

2. To determine the effects of these sources on the quality of water in the receiving streams.

3. To propose possible methods and procedures for reduction of these highly mineralized discharges.

4. To estimate the results of reduction of these discharges on stream quality.

5. To determine the benefits of water quality improvements to present and future municipal, industrial, and agricultural water users.

The investigations were carried out by the Public Health Service's Arkansas-Red River Basins Water Quality Conservation Project, working out of the U.S. Department of Health, Education, and Welfare's regional office at Dallas.

They included intensive study of mineral pollution and its causes, both natural and manmade, on the Arkansas and Red Rivers, together with their tributaries in the middle third of the basins, covering all of water years 1961 and 1962.

They included also an investigation of benefits, which considered the impact of water quality improvement on municipal, industrial, and agricultural water uses. The evaluation of benefits was extended to include areas immediately adjacent to, and forming an integral part of, the Arkansas-Red River Basins. This evaluation extended through the year 2070, with emphasis on the 1970–2020 period.

Acknowledgments

Cooperation and services provided by representatives of many Federal, State, and local agencies, and from industries are gratefully acknowledged. Among those providing such assistance were:

Federal Power Commission

Corps of Engineers

U.S. Department of Agriculture

U.S. Department of Commerce

U.S. Department of the Interior

U.S. Department of Labor

Arkansas-White-Red River Basins Interagency Committee.

Kansas—(1) State Board of Health, (2) Water Resources Board, (3) State Highway Department, (4) local (county and district) departments of health, and (5) Corporation Commission.

Oklahoma—(1) State Department of Health, (2) State Highway Department, (3) Corporation Commission, (4) Water Resources Board, (5) local health departments, and (6) University of Oklahoma.

Texas—(1) State Department of Health, Texas Water Pollution Control Board, (2) State Highway Department, (3) Railroad Commission, (4) Texas Water Commission, (5) Red River Authority (Pollution Control Program), and (6) local health departments.

Arkansas—(1) State Department of Health, (2) Arkansas Water Pollution Control Commission, (3) State Highway Department, and (4) local health departments.

The Arkansas-Red River Basins Water Quality Conservation Project wishes also to express appreciation to the members of its advisory technical review committee who, before and during the intensive portions of the study, gave willingly of their time and talent. The committee included:

Dwight F. Metzler, Executive Secretary, State Water Resources Board, Topeka, Kans., 1957–63.

Richard S. Green, Chief, Basic Data Branch, Division of Water Supply and Pollution Control, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C., 1957–63.

Burdge Irelan, District Chemist, U.S. Geological Survey, Quality Water Branch, Austin, Tex., 1957–61.

A. A. Fischback, Jr., District Engineer, U.S. Geological Survey, Surface Water Branch, Oklahoma City, Okla., 1961–63.

Maurice LeBosquet, Jr., Special Assistant to Chief, Division of Water Supply and Pollution Control, Public Health Service, United States Department of Health, Education, and Welfare, Washington, D.C., 1957–58.

W. W. Towne, Project Director, Columbia River Basin Project, Division of Water Supply and Pollution Control, Public Health Service, U.S. Department of Health, Education, and Welfare, Portland, Oreg., 1958–61.

Frank DeMartini, Chief, Field Operations Section, Technical Services Branch, Division of Water Supply and Pollution Control, Public Health Service, U.S. Department of Health, Education, and Welfare, Robert A. Taft Sanitary Engineering Center, 1961–63.

Summary of Findings

1. Salt (sodium chloride) and, to a lesser extent, gypsum (calcium sulfate) are the principal mineral pollutants of large volumes of surface waters and some ground waters in the Arkansas-Red River Basins. This pollution enters waters of the basins principally as brine from both natural and manmade sources. It is estimated that emissions and releases from these sources, contributing 95 percent of the concentrated brine pollution, represent considerably less than 1 percent of average total streamflow in the basins.

2. The natural brines, ranging in chloride concentration from 20,000 to 190,000 milligrams per liter (mg./l), come from individual large springs, numerous small seeps, large marshes, or salt encrusted flats. Fifteen significant sources of natural mineral pollution, 5 in the Arkansas River Basin and 10 in the Red River Basin, have been located and identified as the primary causes of water quality deterioration with respect to minerals. Nine additional natural salt sources have been located, 3 in the Arkansas River Basin and 6 in the Red River Basin, and classified as of secondary importance.

3. A Geological Survey report on a study carried out for the Public Health Service indicates that, for each natural source of pollution, the fresh water recharge areas and the brine emission points are relatively close to each other, probably within 10 miles.

4. Brines entering the basins' waters resulting from man's activities are largely the consequence of petroleum and natural gas production.

5. Indications from the State water pollution control agencies of Kansas, Oklahoma, and Texas, are that over 95 percent of the brines produced as a result of petroleum and natural gas extraction activities within the Arkansas-Red River Basins is reinjected into the producing strata for secondary petroleum recovery and/or pollution abatement.

6. Some streams, such as the Cimarron River in Oklahoma and the Wichita River in Texas, are polluted primarily by natural brines; while other streams, mainly those of the Canadian River system outside the natural brine producing areas, appear to be polluted only by manmade wastes.

7. During the 2 years (1961–62) of intensive study, an average of 27,000 tons per day of salt (as NaCl) was detected in the Arkansas-Red River Basins upstream from Van Buren, Ark. (near Fort Smith on the Arkansas River) and Index, Ark. (near Texarkana on the Red River). It has been determined that 14,000 tons per day (NaCl) or 53 percent were from primary and secondary sources of natural brine pollution, while the remaining 13,000 tons per day were from other sources, manmade and minor natural.

8. As a result of brine emissions and releases, water quality is seriously degraded so as to be unsuitable for general municipal, industrial, and agricultural use in various tributaries and the main stems of the Arkansas and Red Rivers. According to the drinking water standards adopted by the States and the Public Health Service, the presence in drinking water of either chlorides (as Cl*) or sulfates (as SO_4*) in excess of 250 mg./l is unacceptable, if

*Unless otherwise stated, in this report "chlorides" and "sulfates" refer to Cl^- and $SO_4^=$, respectively.

other more suitable supplies are or can be made available. At average flows, more than 9 million acre-feet of the annual discharges of the Arkansas and the Red Rivers contain chloride concentrations exceeding 250 mg./l. This water quality impairment extends over more than 1,000 stream miles in the middle third of each basin.

9. In addition to chlorides, surface and ground waters of these basins are polluted by sulfates originating in widespread gypsum deposits. The total sulfate loading in the area amounts to about 9,600 tons per day. The principal salt sources account for only 500 tons of sulfate.

10. The following general methods for control of pollution from the natural brine sources have been suggested to the Corps of Engineers:

a. Subsurface disposal of concentrated brines.

b. Permanent storage-retention of concentrated brines in source areas.

c. Elimination of fresh recharge water to the brine generation areas.

d. Imposition of back pressure on brine springs to suppress flow.

e. Transportation of concentrated brines, or solid salt, to nondamaging site (i.e., remote disposal site or Gulf of Mexico).

f. Utilization of salt.

The Corps of Engineers has undertaken preliminary studies of the works required to eliminate or reduce natural mineral pollution. Two field tests of control, by increasing the hydrostatic head on natural springs, were started in 1963. The test at Estelline Spring, Tex., on Prairie Dog Town Fork of the Red River has been successful to date. The test near Guthrie, Tex., on the South Fork, Wichita River, Tex., a tributary of Red River was terminated in February 1964 with the conclusion that the application of hydrostatic head as a means of suppressing individual brine springs in this area or in areas with similar geologic conditions is infeasible.

11. Reduction of mineral pollution by control of the significant natural pollution sources located and defined by this study together with adequate control of manmade sources of mineral pollution will result in water of quality suitable for general municipal, industrial, and agricultural use through nearly all of the basins.

12. Reduction of chloride concentration to 100 mg./l is considered a desirable goal. Availability of water of this quality will encourage maximum water use and development in the basins.

13. If the water quality of the two-river systems is improved sufficiently to meet future water requirements, the average annual value of the benefits over the 100-year period between 1970 and 2070 will amount to $13,076,000 annually.

Recommendations

The findings of the Arkansas-Red River Basins Water Quality Conservation Project have provided a basis for considering control of salt pollution in the two rivers. In accordance with these findings, the Public Health Service, U.S. Department of Health, Education, and Welfare, has developed the following four-point program and recommends it for approval and implementation as rapidly as legislative authority and appropriations permit.

1. As soon as the U.S. Army Engineers designs and costs are available, engineering works should be considered for construction to control natural salt emission at the 15 major sources identified in this report. First priority should be given to three tributaries of the Wichita River, Elm Fork of the Red River, Estelline Spring, and Jonah Creek in Texas, and the Big and Little Salt Plains on the Cimarron River together with the Great Salt Plains on the Salt Fork of the Arkansas River in Oklahoma.

2. The State and the Federal Governments should continue and strengthen their efforts to reduce salt pollution arising from oil fields and other mining and industrial operations, using when appropriate and necessary the enforcement provisions of the Federal Water Pollution Control Act.

3. The Public Health Service should immediately institute a continuous and, where possible, automatic system of water pollution monitoring in the two river basins. Such a system would provide intelligence on water quality in the streams, essential to the efficient operation of those structures which are or may be built in the two basins for quality control. Headquarters for the monitoring and data interpretation would be located at the new regional water pollution control laboratory being built at Ada, Okla.

4. The basin States and the Federal Government should develop a permanent program of mutually acceptable procedures to minimize the salt pollution and its adverse effects at points of water use in the two river basins.

Description of Basins

Topography

The Arkansas and Red River Basins are located in the Southwestern and Central Plains regions and encompass approximately 8 percent of the land area of the United States, containing all or a portion of the eight States of Colorado, New Mexico, Kansas, Oklahoma, Texas, Missouri, Arkansas, and Louisiana. (See figure 14, opposite p. 20.) The combined basins drain a crescent-shaped area of about 254,000 square miles through terrain varying from high rugged mountains over 10,000 feet in elevation in Colorado to coastal and alluvial plains near sea level in Arkansas and Louisiana (*2*).

The Arkansas River rises in the southern Rocky Mountains of Colorado and New Mexico at elevations upwards of 10,000 feet; drops rapidly to the nearly unbroken surface of the high plains at an elevation of about 5,000 feet along the eastern borders of these two States; and then continues southeasterly at more gradual slopes through the high plains, the Ozark-Ouachita uplift, and the Coastal Plain to its confluence with the Mississippi River at an elevation less than 200 feet.

The Red River has its headwaters in the high plains along the western edge of the Texas Panhandle at an elevation of about 4,500 feet. It follows an easterly course forming the border of Oklahoma and Texas and then flows into Arkansas, turns and meanders in a southerly direction through Louisiana where it discharges into the Mississippi River Delta at an elevation less than 100 feet.

The general appearance of both basins is one of smooth plains with distinct escarpments facing the northwest and growing in predominance toward the headwaters. The rivers, beginning in Colorado, originate as swift-flowing mountain streams with rocky bottoms. As they flow into the high plains region, the rivers become broad, shallow, and generally choked with sand. In the Ozark-Ouachita uplift area, the streams are once again fairly swift and clear, only to become sluggish and meandering upon reaching the Coastal Plain.

Hydrology

Average annual precipitation varies from about 55 inches near the mouth of the Red River to 50 inches at the mouth of the Arkansas River. Moving westward, the isohyets are generally oriented north to south and fairly evenly spaced to a low of about 12 inches along the western edge of the Great Plains. Continuing westward, rainfall increases with elevation, reaching a peak of some 32 inches on the eastern slopes of the Rocky Mountain chain in Colorado and New Mexico. Because of the differences in geography within the Arkansas-Red River Basins, the seasonal distribution of precipitation varies widely. In the Coastal Plain, the seasonal distribution is quite uniform, while in the Great Plains and Rocky Mountain regions rainfall reaches a peak in the summer due to convective or thundershower-type activity.

In much of the Arkansas-Red River Basins, ground waters have supplied essential needs. The bulk of the basins lies in five ground water provinces (*3*).

The westernmost portion of the Arkansas River Basin lies in the southern Rocky Mountain province which is underlain for the most part by crystalline rocks. Water is obtained chiefly from springs or spring fed streams, or very shallow wells near the streams.

Moving eastward, part of the Arkansas River Basin in eastern Colorado and Kansas is in the Great Plains province. The principal aquifers of this area are the geologically Recent sands and gravels (Ogallala) and the Dakota sandstone, both of which yield large quantities of good quality water. The Ogallala is shallow, while the Dakota sandstone may be too deep for a practical source of water supply in parts of the area. Many valleys also contain gravels of Recent geologic age which supply large quantities of good water.

South of the above province and underlying the Texas and Oklahoma Panhandles and reaching up into Kansas is an earlier Great Plains province. The principal aquifers here are the Recent sands and gravels which give the same favorable ground water conditions as those in the province above. The earliest of these deposits are, however, underlain by red beds which yield little or only highly mineralized water. The ground water conditions are generally unfavorable.

The middle portions of the basins extending into northwestern Arkansas are in the south central province, where ground water conditions are, in general, rather unsatisfactory. The principal sources

of supply are the early sandstones and limestones, containing waters which are for the most part meager or of poor quality. Deep water is highly mineralized. Large supplies are obtained from glacial outwash and other alluvial sands and gravels in many of the valleys.

The remainder of the basins lies in the Atlantic Coastal Plain province, where water is obtained in rather large quantities from Recent strata, chiefly sand and gravel interbedded with clay. The alluvium of the Mississippi Valley provides large supplies of good quality water.

Streamflow in these basins is highly variable. In western Oklahoma and Texas, most of the tributary streams are intermittent, while in the lower basins more evenly distributed streamflow is evident. The highest coefficients of variation of streamflow occur between the Colorado-New Mexico border and the eastern border of Oklahoma. These range from 50 percent at both the eastern and western limits to a high of 72 percent in the Neosho River near Parsons, Kans. (*4*). The average annual runoff varies from a low of 0.25 inch in the western part of the Great Plains to a high of 20 inches in parts of Arkansas and Louisiana (*5*).

Definition of Study Area

The study area as shown in figure 14 encompasses all of the Arkansas and Red River Basins plus minor adjoining portions of the Missouri, White, Trinity, Brazos, and Sabine River Basins. This area consists of a total of 327 counties in Colorado, New Mexico, Kansas, Oklahoma, Texas, Missouri, Arkansas, and Louisiana, and represents approximately 9 percent of the land area and 5 percent of the population of continental United States.

The study area includes all counties partly or entirely within the Arkansas-Red River Basins together with those adjoining counties which are expected to be directly affected by an improvement in the water quality of the mineral polluted streams.

The water quality monitoring studies cover about 60 percent of the area of the Arkansas-Red River Basins ranging, on the Arkansas River, from Great Bend, Kans. to Van Bruen, Ark., and, on the Red River, from Brice, Tex., to Index, Ark. (near Texarkana, Tex.). These limits were established because they include practically all of the poor quality water and all of the known primary natural salt sources. The major portion of oil-gas brine pollution also occurs within this area.

Economy

The economy of the Arkansas-Red River Basins study area is diversified. In land area it covers 302,000 square miles, most of it unpopulated and relatively barren. On the other hand, over 9,300,000 people reside in the area, largely in metropolitan areas varying in size from Dallas with a 1960 population of over a million to cities such as Oklahoma City, Tulsa, and Forth Worth with 1960 populations of about one-half million and Lawton, Okla.; Fort Smith, Ark.; and Texarkana, Tex., and Ark., with 1960 populations of less than 100,000 (*6*). The population growth rate of the entire area from 1950 to 1960 has been 1 percent compounded annually. The national rate was 1.75 percent over the same period.

The population trend in the study area reflects the national condition of rural area decline and urban area increase. This change is due to reduction of farm employment opportunities resulting from development of mechanized, large-scale agriculture and to the consequent exodus of the surplus farm labor to the cities, as well as to other migration and social factors.

The study area lost 15 percent of its rural population from 1950 to 1960; the totals were 4,320,000 in 1950 and 3,670,000 in 1960. The urban population grew by 37 percent over the same 10-year period, from 4,120,000 to 5,660,000 (*6*). The national rates for these two segments of the population were increases of one-third of 1 percent and 30 percent, respectively, for the same period of time.

These comparisons of national with Arkansas-Red River Basins study area population trends indicate that the study area compares favorably with the Nation in growth. This favorable comparison is particularly manifest in the large metropolitan areas (SMSA's*) of the region such as Dallas, Fort Worth, Oklahoma City, Tulsa, Wichita, and Shreveport, which had a population growth rate of 3.25 percent compounded annually from 1950 to 1960. The national rate in these population categories was 2.625 percent. A detailed picture of the SMSA populations in the study area is presented in table 1 and figure 1.

The diversity of the study area's economy is also indicated by the distribution of the labor force among the several major sectors of employment.

*Standard Metropolitan Statistical Area—A central city with a population of 50,000 or more and its urbanized fringe area.

TABLE 1.—Study Area Population—Total, Urban, Rural, and Standard Metropolitan Statistical Area 1910–60 (Millions)

Population component	1910	1920	1930	1940	1950	1960
Total	6.1	7.1	8.0	8.1	8.4	9.3
Urban	1.3	1.9	2.7	3.0	4.1	5.6
Rural	4.8	5.2	5.3	5.1	4.3	3.7
SMSA**	.6	1.2	1.8	2.1	3.1	4.3

**SMSA populations for all decades adjusted to include geographic area defined as SMSA in 1960.
Source: Bureau of the Census (7).

For instance, in 1960, 9 percent of a total labor force of 3,370,000 was employed in agriculture; 3 percent was employed in mining, chiefly petroleum and gas drilling; and 17 percent was employed in manufacturing (*8*). Based on the 1950 and 1960 trend, the significant changes in the labor force have been in the agriculture and manufacturing categories. The similarity to the national condition is again manifest in these figures.

The geographic distribution of the labor force is virtually self-evident. The largest percentage is highly urban, particularly metropolitan urban. Since the growth industries are urban metropolitan in their location, it can be seen that the major share of future population growth is likely to occur within the present metropolitan areas. These are the areas that can provide the technical, personal, and business services. Large-scale manufacturing is especially dependent on these services, as well as on the transportation facilities, markets, and labor force accumulations of large metropolitan and urban areas. On the other hand, manufacturing activities less dependent on labor and area markets, chiefly those activities based directly on raw materials such as timber and agricultural crops, often locate in small communities or in rural areas apart from the large population centers. These activities influence the "scatter" of population—its number of centers and the density pattern.

The most conspicuous single feature of the economy of the basins is the prominence of petroleum and natural gas extraction in the creation of wealth and employment. The study area ranks high on the national scale in both volume of production and sales value. In 1960, oil production reached 0.6 billion barrels and gas production reached 3.5 trillion cubic feet. The sales values were $1.7 billion and $½ billion, respectively. This extraction of petroleum and natural gas accounted for approximately one-fourth of the national production (*9*). Figure 2 reveals the general location of oil and gas extraction in the study area (*10*).

Description of Problem

The principal mineral pollutants in the Arkansas-Red River Basins waters are salts—sodium chloride and calcium sulfate (*11*). The 1955 report of the Arkansas-White-Red River Basins Interagency Committee refers to the significance of salt pollution (*12*). As shown in figure 3, natural deposits of both minerals are widely distributed. Some salt pollution also results from oil-gas production in the basins, but effective State water pollution control programs are expected to continue to reduce this pollution entering both surface and ground waters.

With ever-increasing water demands, municipalities such as Dallas, Fort Worth, Oklahoma City, Wichita Falls, and Tulsa are reaching considerable distances for good quality water. Oklahoma City, for example, has reached some 100 miles to the southeast of the city for additional water of adequate quality to meet rising needs. The Canadian River, which is located about 20 miles away, is unsuitable for municipal use due to its excessive mineral content.

Even so, it has been necessary for some municipalities to use highly mineralized waters. During the drought of the 1950's, the water supply of Dallas became depleted and the city was forced to take a large portion of its water from the Red River. During a period extending from August 1953 to April 1957, 34,600 million gallons or 110,000 acre-feet of water from the Red River with undesirable chloride concentrations were used by the Dallas water supply system (*13*). Based upon water quality records at a Geological Survey station located 1½ miles, more or less, downstream from the city's provisional Red River pump station, chloride concentrations ranged from 114 mg./l to 2,000 mg./l during this time (*14*). It is estimated that the salt (NaCl) load in the Dallas system from this source amounted to about 150,000 tons during this period of emergency use. Considerable damage, caused by the high salt concentration, was reported by water department officials. Insurance adjustments and income tax deductions were claimed because of hot water tank cor-

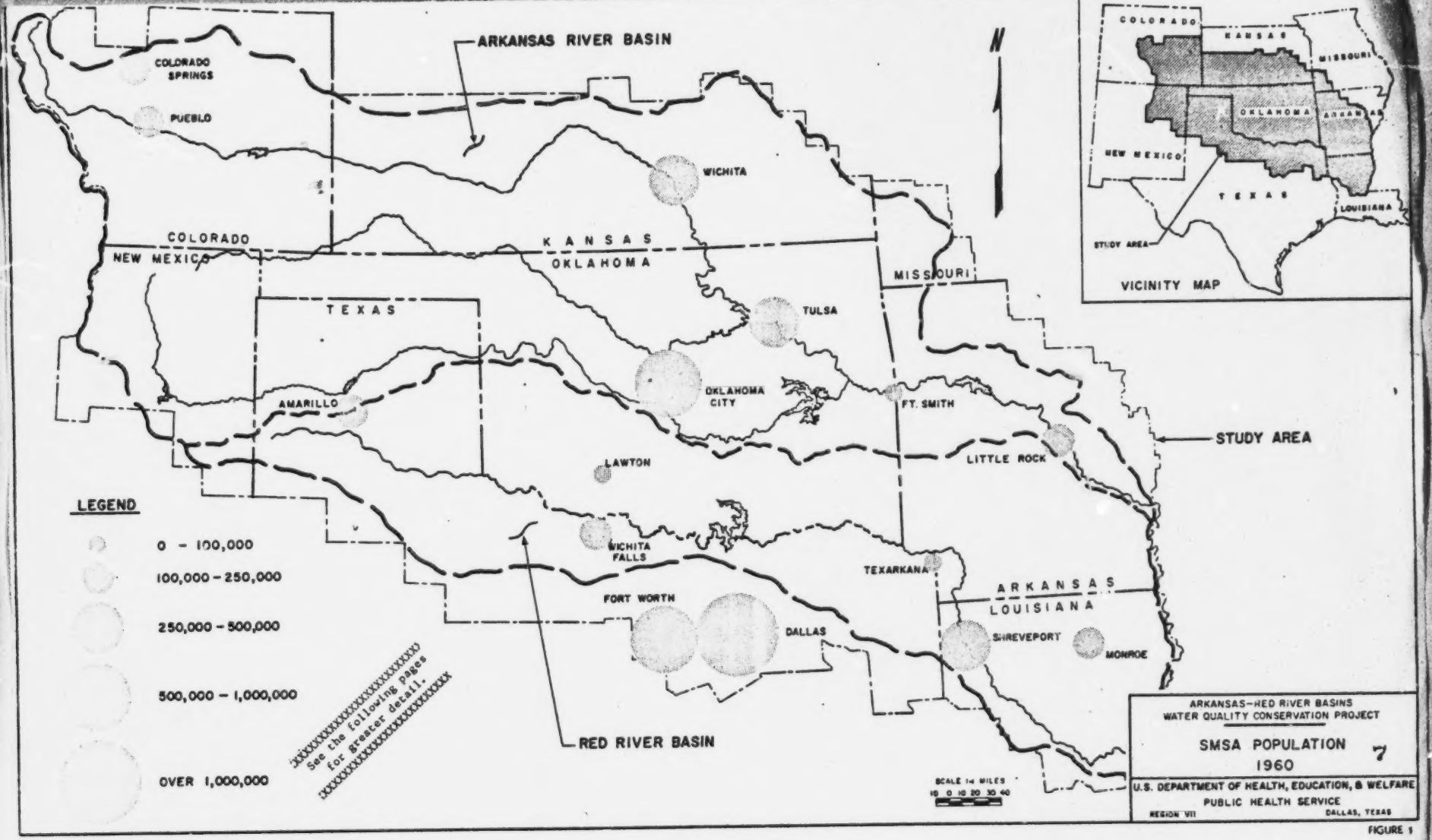

ARKANSAS RIVER BASIN
COLORADO SPRINGS
PUEBLO
WICHITA
COLORADO
NEW MEXICO
KANSAS
OKLAHOMA
MISSOURI
TEXAS
TULSA
OKLAHOMA CITY
AMARILLO
FT. SMITH
LITTLE ROCK
STUDY AREA
LAWTON
WICHITA FALLS
TEXARKANA
ARKANSAS
LOUISIANA
FORT WORTH
DALLAS
SHREVEPORT
MONROE
RED RIVER BASIN
LEGEND
0 - 100,000
100,000 - 250,000
250,000 - 500,000
500,000 - 1,000,000
OVER 1,000,000
See the following pages for greater detail.
SCALE IN MILES
10 0 10 20 30 40
N
COLORADO
KANSAS
MISSOURI
OKLAHOMA
ARKANSAS
NEW MEXICO
TEXAS
LOUISIANA
STUDY AREA
VICINITY MAP
ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT
SMSA POPULATION
1960
7
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII
DALLAS, TEXAS

FIGURE 1

rosions, as well as other damage to plumbing, shrubbery, and vegetation. Many users, by necessity or choice, obtained water of more acceptable quality from outside sources.

The full development and use of all the streams of satisfactory quality which are located reasonably close to the population centers are foreseeable in many parts of the basins. Future needs, rapidly becoming apparent, may well need to be supplied by waters presently carrying objectionable loads of chlorides and sulfates. Furthermore, unanticipated growth in a particular area and/or another severe drought may at any time require emergency use of salt-polluted streams.

Study Methods

Personnel in the Public Health Service regional office in Dallas, Tex., working with State and local officials, and with the advice and guidance of a technical review committee, developed a study procedure for both basins. Sixty-four monitoring stations, 37 on the Arkansas River and its tributaries and 27 on the Red River system, were established for this 2-year field study. (Locations and designations are shown on figure 4.)

The monitoring stations were located so that chloride and sulfate contributions from both natural and manmade sources, including gas and oil production, could be measured. Wherever possible, the stations were established where streamflow gaging stations existed.

Because this study covered only a relatively short period of time and because of the sudden brief variations in salt load during rainy periods, especially at upstream stations with low flows, continuous monitoring was considered necessary. Electrical conductance recorders, suitable for continuous mineral content monitoring, were installed at all 64 monitoring sites during the late spring and early summer of 1960.

Chemical analyses of grab samples taken at monitoring stations showed reasonably good correlation between chlorides and conductance. Acceptable correlation was also demonstrated for sulfates at most stations. Grab samples were collected at least weekly and the results of laboratory analyses for conductance, chlorides, sulfates, and dissolved solids were used in computing the correlations.

Streamflow hydrographs are necessary for computing daily or instantaneous tonnage of chlorides, sulfates, and dissolved solids. Twenty-five additional flow-gaging stations were, therefore, installed to augment existing stations. All of the new stations were installed and operated by the Geological Survey, Surface Water Branch, and, where possible, were established to serve the needs of other Federal, State, or local agencies. The New Mexico, Kansas, Oklahoma, Texas, and Arkansas district offices of the Geological Survey, Surface Water Branch, and the Corps of Engineers, Tulsa District, provided provisional (preliminary) subdivided daily streamflow reports for each station so that a flow hydrograph could be reproduced.

Location and Measurement of Natural Salt Emissions

Natural saltwater emission areas were located from published and unpublished reports. Airplane surveys were made to pinpoint reported sources and locate others. Field investigations of each source were undertaken to locate and define specific springs, seeps, and other brine-drainage areas. Brineflows and concentrations were determined for each salt source area and, where possible, individual emissions in an area were measured. As stated above, where feasible, a continuous conductivity recorder station was operated downstream to measure the salt load, its variations, and its effects on the stream.

Manmade Salt Sources

Estimates of salt discharged from oil and gas operations as well as information regarding disposal practices were obtained from the State agencies responsible for these practices.

Results of Field Study

In any pollution study, the volume or rate of streamflow is an important factor in the determination of the pollutant loads (tons) and the average water quality. In general, higher flows carry larger loads of minerals but with lower concentrations.

Long-term streamflow gaging stations were located downstream from two of the natural brine sources in the Arkansas River Basin. Results at these stations and other stations in the two basins were used to compare the flows observed during the study period with long-run averages. The flow below the Great Salt Plains on the Salt Fork of the Arksansas River near Jet, Okla., during 1961 and 1962, was about average; the flow in the Cimarron River near Waynoka, Okla., was about 60 percent of the long-term average. The 2-year average flow in the Arkansas River at Van Buren, Ark., was 20 percent larger than the long-term average, with most of the excess above average flow contributed by the better quality tributaries in eastern Oklahoma. The streamflows and rainfall in the vicinities of other significant natural salt sources appear to have been about average. The flow in the Red River into Lake Texoma was slightly below average.

The long-term average flows and the annual average flows for the period of intensive study (1961–62 water years) are summarized in tables 2 and 3.

Stream Quality

Weighted values shown in this report are based on a time, flow, and continuously recorded specific conductance relationship. Correlation equations, derived from laboratory analyses of weekly grab samples, and weighted average specific conductance, were used to compute average mineral constituent concentrations in mg./1. Average loads are computed from average concentrations and discharge during periods of recorded specific conductance.

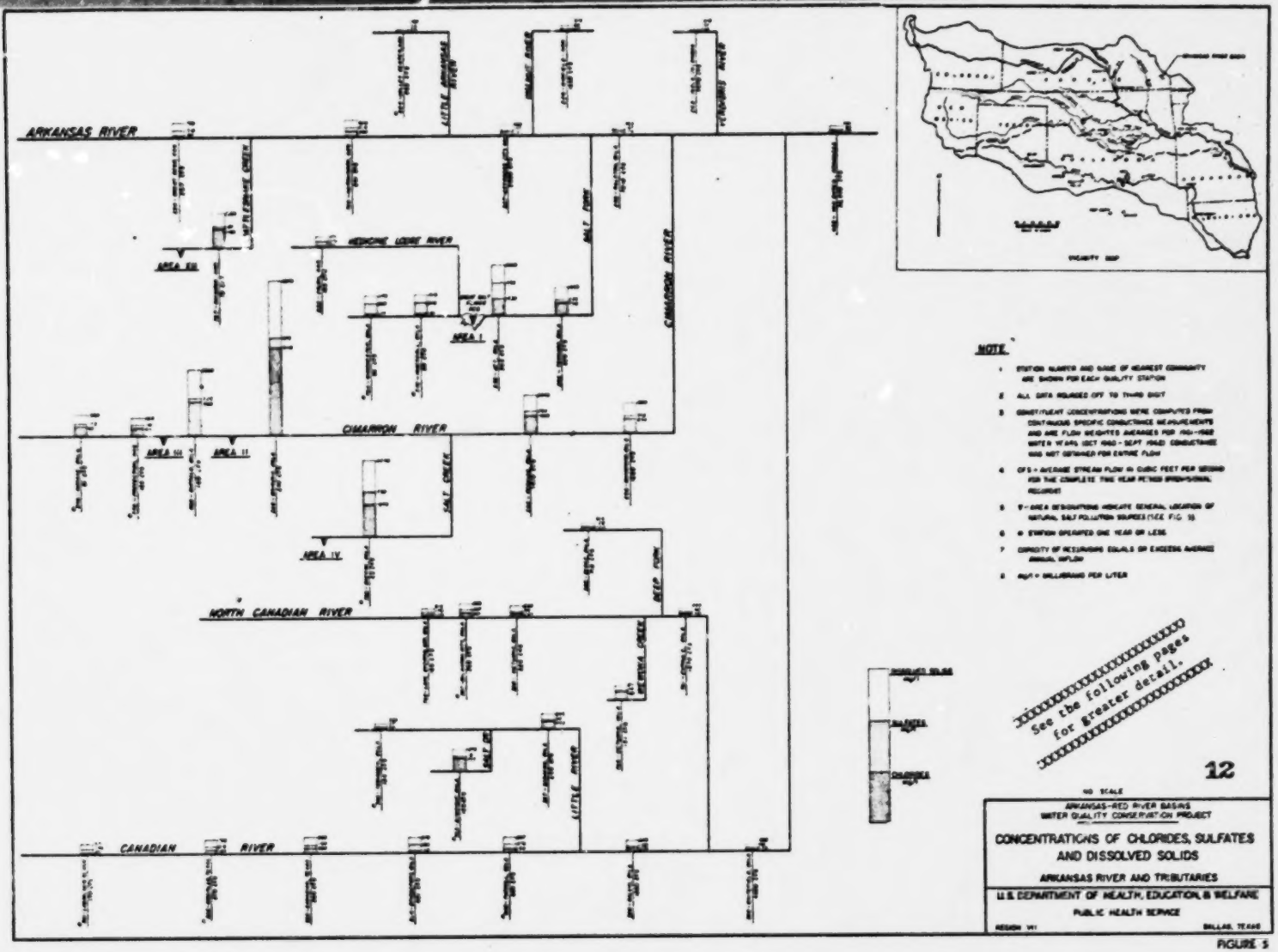
Weighted average streamflows and weighted average concentrations of chlorides, sulfates, and dissolved solids, for 24 consecutive months, water years

TABLE 2.—Comparison of Flows During Study With Long-Term Average Annual Flows, Arkansas River

Station number and location	Years of record	Annual average streamflow (cfs)	
		Long-term*	1961–62 water years
220—Arkansas River near Great Bend, Kans.	22	452	257
224—Little Arkansas River at Valley Center, Kans.	40	251	493
227—Arkansas River at Arkansas City, Kans.	45	1,782	2,625
229—Walnut River at Winfield, Kans.	41	765	1,548
232—Medicine Lodge River near Kiowa, Kans.	17	154	102
235—Salt Fork of Arkansas River near Jet, Okla.	25	404	364
236—Salt Fork of Arkansas River near Tonkawa, Okla.	27	713	823
238—Arkansas River at Ralston, Okla.	37	4,749	7,268
246—Cimarron River near Mocane, Okla.	20	100	81
248—Cimarron River near Waynoka, Okla.	25	420	272
253—Cimarron River near Perkins, Okla.	23	1,293	1,406
258—Cimarron River near Mannford, Okla.	15	1,785	1,889
283—Verdigris River near Inola, Okla.	18	4,483	7,488
361—Canadian River at Logan, N. Mex.	34	308	170
362—Canadian River near Amarillo, Tex.	25	451	280
363—Canadian River near Canadian, Tex.	24	590	269
364—Canadian River near Bridgeport, Okla.	18	507	476
366—Little River near Tecumseh, Okla.	19	160	107
367—Little River near Sasakwa, Okla.	20	440	245
368—Canadian River at Calvin, Okla.	23	1,972	1,388
387—North Canadian River near Oklahoma City, Okla.	16	381	268
388—North Canadian River near Wetumka, Okla.	25	771	525
390—Deep Fork near Beggs, Okla.	24	909	715
392—Canadian River near Whitefield, Okla.	24	6,173	4,520
403—Arkansas River at Van Buren, Ark.	35	32,080	38,900
762—North Canadian River below Lake Overholser, Okla.	10	149	169
770—Arkansas River at Haskell, Okla.	37	6,750	10,100
772—Salt Fork of Arkansas River at Ingersoll, Okla.	1	87	90

*Source: Geological Survey (*15*).

10-8


ARKANSAS RIVER
HEGINS LOAD RIVER
AREA III
AREA I
CIMARRON RIVER
AREA II
AREA II
SALT CREEK
AREA IV
NORTH CANADIAN RIVER
CANADIAN RIVER
NOTE
See the following pages for greater detail.
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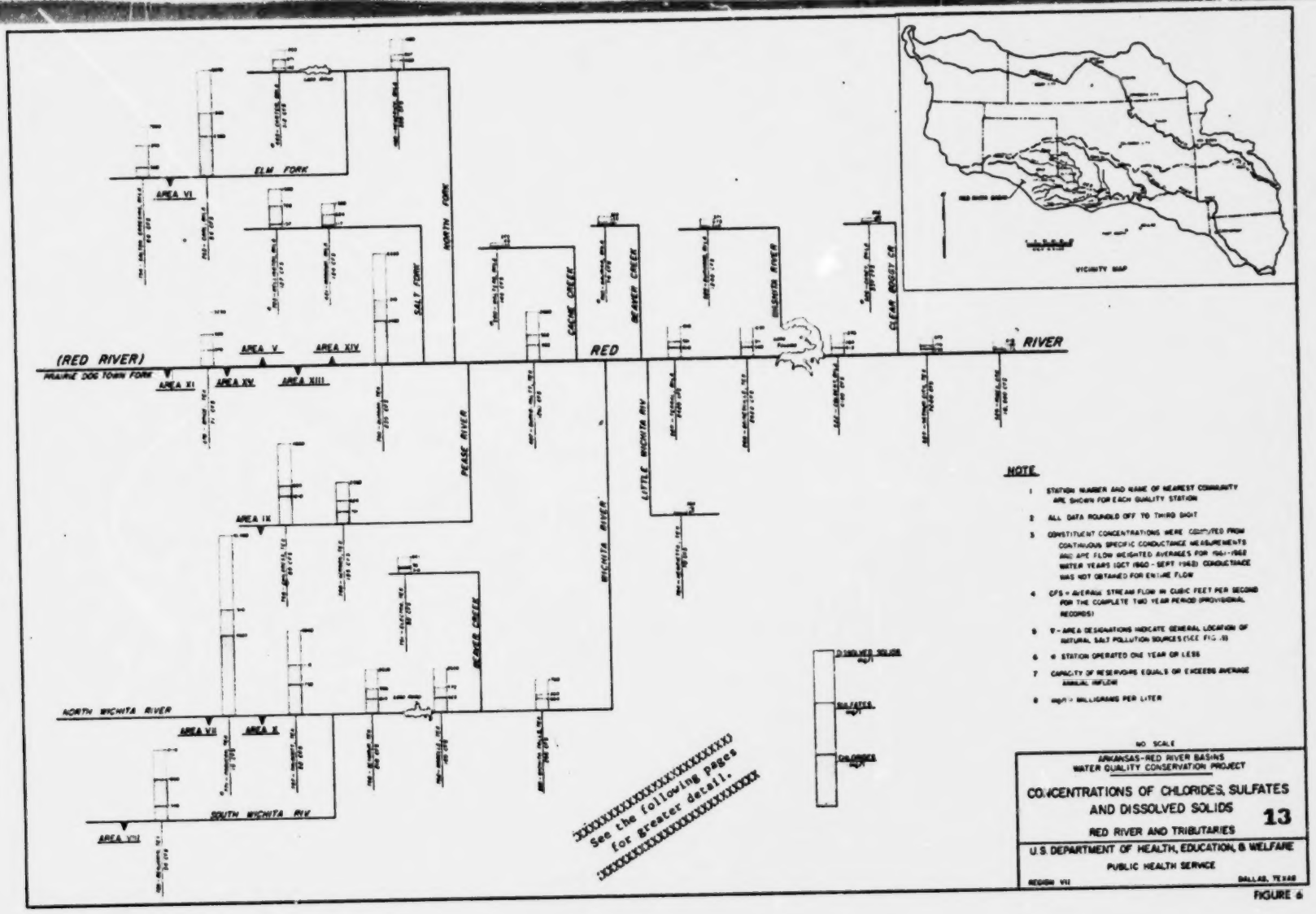
NO SCALE
ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT
CONCENTRATIONS OF CHLORIDES, SULFATES AND DISSOLVED SOLIDS
ARKANSAS RIVER AND TRIBUTARIES
U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE

FIGURE 5



NOTE

1. STATION NUMBER AND NAME OF NEAREST COMMUNITY ARE SHOWN FOR EACH QUALITY STATION
2. ALL DATA ROUNDED OFF TO THIRD DIGIT
3. CONSTITUENT CONCENTRATIONS WERE COMPUTED FROM CONTINUOUS SPECIFIC CONDUCTANCE MEASUREMENTS AND ARE FLOW WEIGHTED AVERAGES FOR 1961-1965 WATER YEARS (OCT 1960 - SEPT 1965) CONDUCTANCE WAS NOT OBTAINED FOR ENTIRE FLOW
4. CFS = AVERAGE STREAM FLOW IN CUBIC FEET PER SECOND FOR THE COMPLETE TWO YEAR PERIOD (PROVISIONAL RECORDS)
5. V - AREA DESIGNATIONS INDICATE GENERAL LOCATION OF NATURAL SALT POLLUTION SOURCES (SEE FIG. 3)
6. # STATION OPERATED ONE YEAR OR LESS
7. CAPACITY OF RESERVOIRS EQUALS OR EXCEEDS AVERAGE ANNUAL INFLOW
8. mg/l = MILLIGRAMS PER LITER

NO SCALE

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

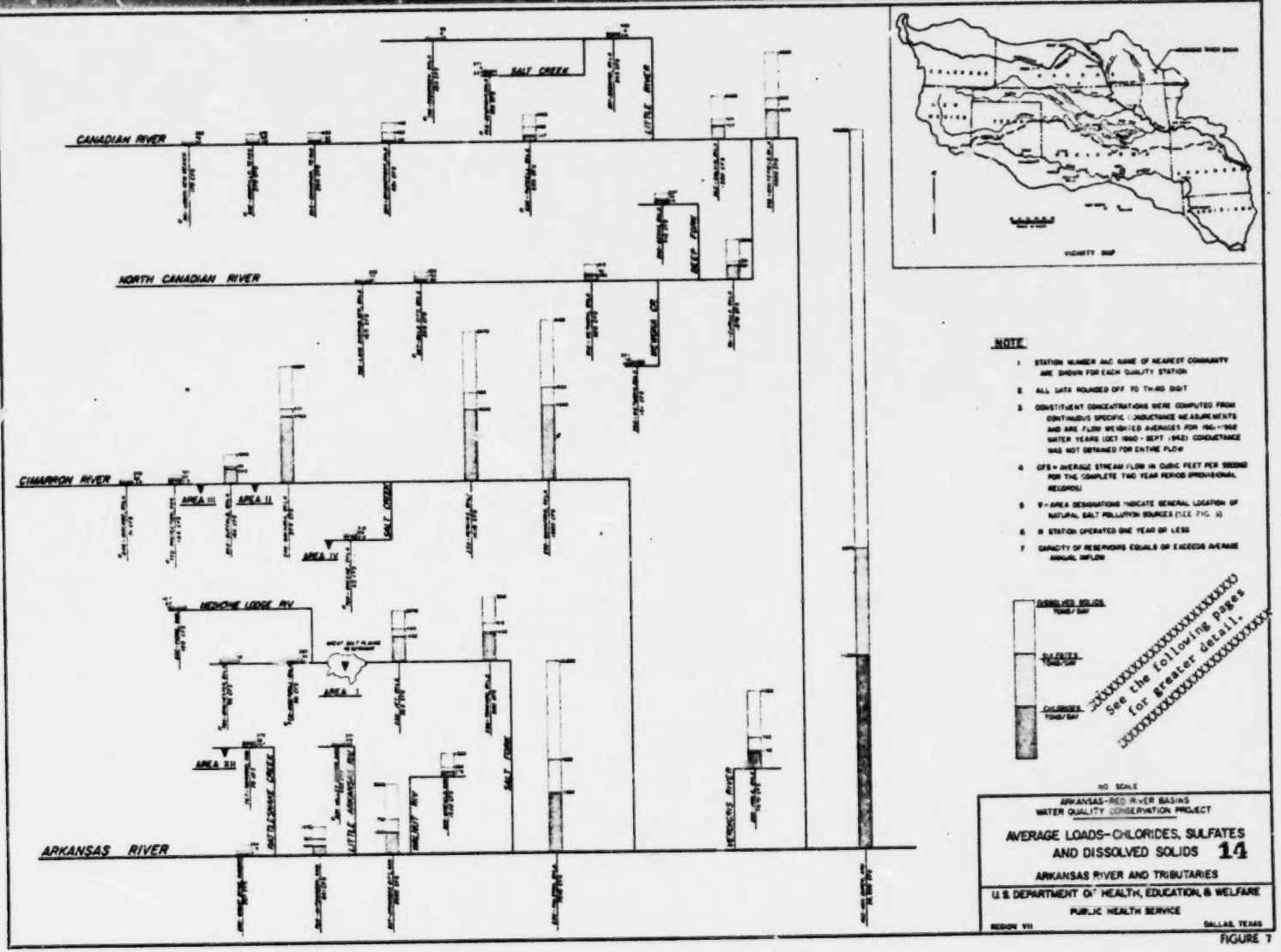
CONCENTRATIONS OF CHLORIDES, SULFATES AND DISSOLVED SOLIDS

RED RIVER AND TRIBUTARIES

13

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 6


SALT CREEK
CANADIAN RIVER
NORTH CANADIAN RIVER
CIMARRON RIVER
AREA III
AREA II
AREA IV
MEDICINE LODGE RIV.
AREA I
AREA VII
ARKANSAS RIVER
VICINITY MAP
NOTE
1 STATION NUMBER AND NAME OF NEAREST COMMUNITY ARE SHOWN FOR EACH QUALITY STATION
2 ALL DATA ROUNDED OFF TO THREE DIGIT
3 CONSTITUENT CONCENTRATIONS WERE COMPUTED FROM CONTINUOUS SPECIFIC CONDUCTANCE MEASUREMENTS AND ARE FLOW WEIGHTED AVERAGES FOR 1961-1962 WATER YEARS (OCT 1960 - SEPT 1962) CONDUCTANCE WAS NOT OBTAINED FOR ENTIRE FLOW
4 CFS = AVERAGE STREAM FLOW IN CUBIC FEET PER SECOND FOR THE COMPLETE TWO YEAR PERIOD (PROVISIONAL RECORDS)
5 V = AREA DESIGNATIONS INDICATE GENERAL LOCATION OF NATURAL SALT POLLUTION SOURCES (SEE FIG. 3)
6 # STATION OPERATED ONE YEAR OR LESS
7 CAPACITY OF RESERVOIRS EQUALS OR EXCEEDS AVERAGE ANNUAL INFLOW
DISSOLVED SOLIDS TONS/DAY
SULFATES TONS/DAY
CHLORIDES TONS/DAY
See the following pages for greater detail.

NO SCALE

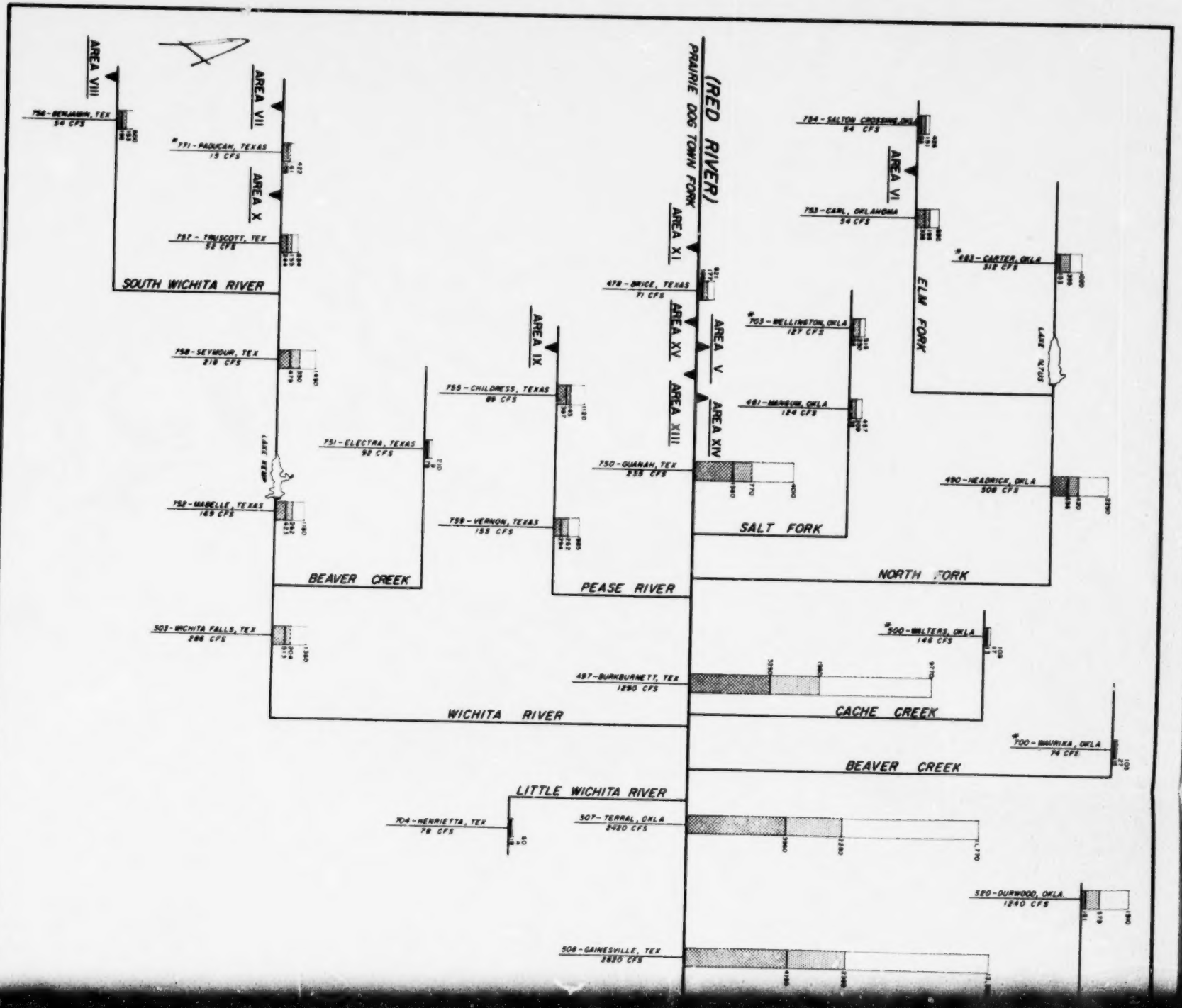
ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

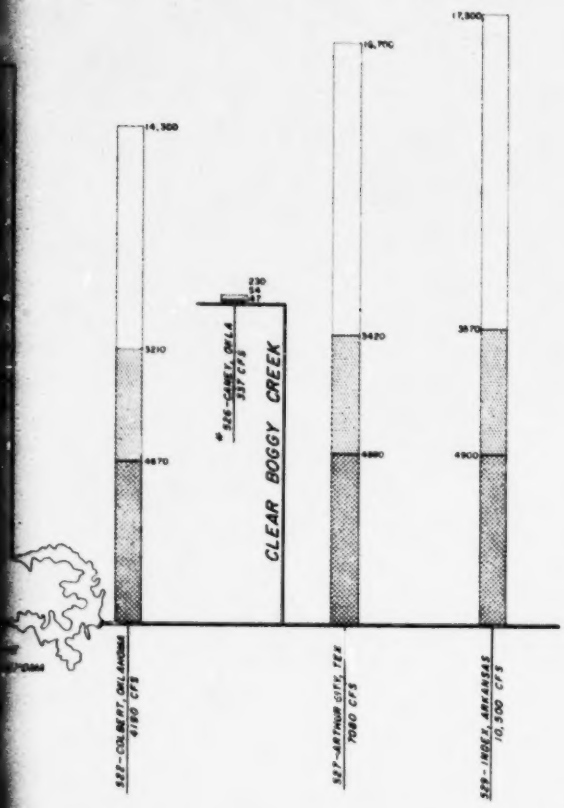
AVERAGE LOADS-CHLORIDES, SULFATES AND DISSOLVED SOLIDS 14

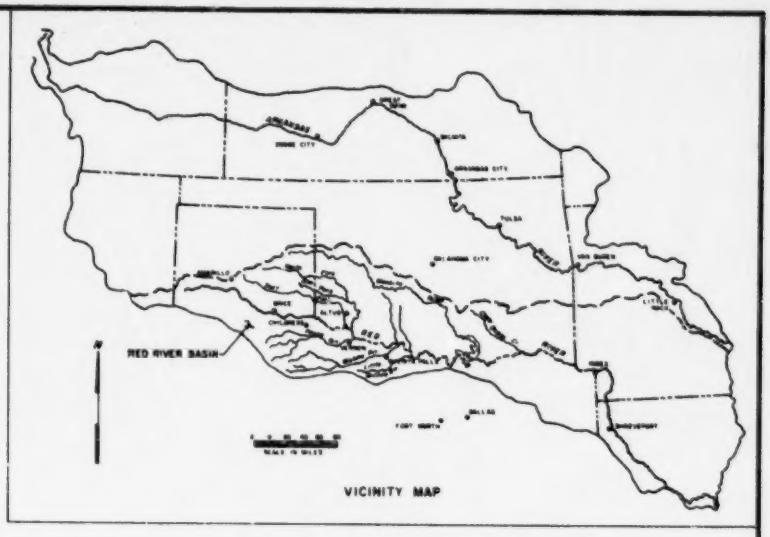
ARKANSAS RIVER AND TRIBUTARIES

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 7


AREA VIII
AREA VII
AREA X
AREA XI
AREA XV
AREA XIII
AREA IX
AREA V
AREA XIV
AREA VI
(RED RIVER)
PRAIRIE DOG TOWN FORK
SOUTH WICHITA RIVER
BEAVER CREEK
WICHITA RIVER
PEASE RIVER
SALT FORK
NORTH FORK
ELM FORK
LAKE ALTUS
CACHE CREEK
BEAVER CREEK
LITTLE WICHITA RIVER
756 - BENJAMIN, TEX
54 CFS
*771 - PADUCAH, TEXAS
19 CFS
757 - TRUSCOTT, TEX
52 CFS
758 - SEYMOUR, TEX
218 CFS
751 - ELECTRA, TEXAS
92 CFS
752 - MABELLE, TEXAS
169 CFS
503 - WICHITA FALLS, TEX
286 CFS
759 - CHILDRESS, TEXAS
89 CFS
758 - VERNON, TEXAS
155 CFS
478 - BRICE, TEXAS
71 CFS
750 - QUANAH, TEX
233 CFS
497 - BURKBURNETT, TEX
1290 CFS
704 - HENRIETTA, TEX
78 CFS
507 - TERRAL, OKLA
2480 CFS
508 - GAINESVILLE, TEX
7830 CFS
754 - SAYTON CROSSING, OKLA
54 CFS
753 - CARL, OKLAHOMA
54 CFS
*483 - CARTER, OKLA
318 CFS
*703 - WELLINGTON, OKLA
127 CFS
481 - MANGUM, OKLA
124 CFS
490 - HEADRICK, OKLA
508 CFS
*500 - WALTERS, OKLA
146 CFS
*700 - MARIETTA, OKLA
74 CFS
520 - DURWOOD, OKLA
1240 CFS





NOTE

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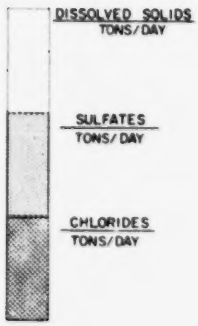
2. ALL DATA ROUNDED OFF TO THIRD DIGIT
3. CONSTITUENT CONCENTRATIONS WERE COMPUTED FROM CONTINUOUS SPECIFIC CONDUCTANCE MEASUREMENTS AND ARE FLOW WEIGHTED AVERAGES FOR 1961-1962 WATER YEARS (OCT 1960 - SEPT 1962) CONDUCTANCE WAS NOT OBTAINED FOR ENTIRE FLOW
4. CFS = AVERAGE STREAM FLOW IN CUBIC FEET PER SECOND FOR THE COMPLETE TWO YEAR PERIOD (PROVISIONAL RECORDS)
5. ▼ - AREA DESIGNATIONS INDICATE GENERAL LOCATION OF NATURAL SALT POLLUTION SOURCES (SEE FIG. 9).
6. * STATION OPERATED ONE YEAR OR LESS
7. CAPACITY OF RESERVOIRS EQUALS OR EXCEEDS AVERAGE ANNUAL INFLOW



NO SCALE

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

AVERAGE LOADS-CHLORIDES, SULFATES AND DISSOLVED SOLIDS

RED RIVER AND TRIBUTARIES

15

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII — DALLAS, TEXAS

FIGURE 8

Table 4.—Arkansas River Basin—Selected Stations—Quantity and Percentage of Water of Various Qualities (October 1960–September 1962)

Station number, stream and location	Total flow (acre-feet)	Acre-feet of water (and percent of total) of following specific conductance, micromhos/cm*						
		0-500	500-1,000	1,000-1,500	1,500-2,500	2,500-5,000	5,000-10,000	10,000-30,000
Oct. 1960–Sept. 1961 (Water Year 1961)								
220—Arkansas River at Great Bend, Kans.	136,700	43,800 32.0%	29,700 21.7%	50,700 37.1%	12,500 9.2%	31 0%	4 0%	0 0%
227—Arkansas River at Arkansas City, Kans.	1,719,000	560,500 32.6%	446,100 26.0%	275,200 16.0%	436,500 25.4%	793 0%	0 0%	0 0%
238—Arkansas River at Ralston, Okla.	5,430,000	2,155,000 39.7%	1,354,000 24.9%	969,900 17.9%	949,200 17.5%	2,740 0%	0 0%	0 0%
403—Arkansas River at Van Buren, Ark.	31,590,000	18,288,600 57.9%	10,5[illegible],200 33.5%	2,465,000 7.8%	279,500 .8%	0 0%	0 0%	0 0%
229—Walnut River at Winfield, Kans.	1,202,000	781,700 65.0%	2[illegible],300 23.7%	106,800 8.9%	28,400 2.4%	0 0%	0 0%	0 0%
236—Salt Fork of Arkansas River at Tonkawa, Okla.	670,600	49,500 7.4%	65,300 9.7%	86,700 12.9%	120,700 18.0%	333,200 49.7%	15,200 2.3%	0 0%
253—Cimarron River at Perkins, Okla.	1,051,000	151,600 14.4%	117,400 11.2%	123,700 11.8%	145,200 13.8%	225,800 21.5%	242,700 23.1%	44,500 4.2%
283—Verdigris River near Inola, Okla.	6,495,000	6,060,000 93.3%	426,500 6.6%	8,540 .1%	8 0%	0 0%	0 0%	0 0%
392—Canadian River at Whitefield, Okla.	3,169,000	1,072,000 33.8%	1,481,000 46.7%	566,300 17.9%	49,700 1.6%	0 0%	0 0%	0 0%
Oct. 1961–Sept. 1962 (Water Year 1962)								
220—Arkansas River at Great Bend, Kans.	236,200	97,000 41.1%	39,700 16.8%	26,800 11.3%	55,400 23.5%	17,300 7.3%	0 0%	0 0%
227—Arkansas River at Arkansas City, Kans.	2,055,000	794,000 38.7%	486,900 23.7%	253,400 12.3%	516,100 25.1%	4,720 .2%	0 0%	0 0%
238—Arkansas River at Ralston, Okla.	5,006,000	1,602,200 32.0%	1,183,300 23.6%	859,700 17.2%	1,360,000 27.2%	0 0%	0 0%	0 0%
403—Arkansas River at Van Buren, Ark.	24,682,000	7,234,000 29.3%	14,952,000 60.6%	2,114,000 8.6%	382,800 1.5%	0 0%	0 0%	0 0%
229—Walnut River at Winfield, Kans.	1,013,000	571,700 56.4%	242,100 23.9%	197,200 19.5%	2,450 .2%	0 0%	0 0%	0 0%
236—Salt Fork Arkansas River at Tonkawa, Okla.	517,200	101,600 19.6%	41,400 8.0%	13,900 2.7%	47,700 9.2%	272,800 52.8%	39,700 7.7%	0 0%
253—Cimarron River at Perkins, Okla.	984,100	23,200 2.4%	220,700 22.4%	75,200 7.6%	83,800 8.5%	189,600 19.3%	377,800 38.4%	13,900 1.4%
283—Verdigris River near Inola, Okla.	4,027,000	2,490,000 61.8%	1,523,000 37.8%	13,800 .4%	106 0%	0 0%	0 0%	0 0%
392—Canadian River at Whitefield, Okla.	3,383,000	1,459,000 43.1%	1,435,000 42.4%	428,800 12.7%	61,000 1.8%	0 0%	0 0%	0 0%

*Average of all waters below 1,000 micromhos/cm conductance, when combined, is considered to meet Public Health Service drinking water standards.

TABLE 3.—Comparison of Flows During Study With Long-Term Average Annual Flows, Red River

Station number and location	Record	Annual average streamflow (cfs)	
		Long-term*	1961–62 water years
478—Red River near Brice, Tex	7	85	71
481—Salt Fork of Red River at Mangum, Okla	25	97	124
483—North Fork of Red River near Carter, Okla	18	138	215
490—North Fork of Red River near Headrick, Okla	27	347	508
500—Cache Creek near Walters, Okla	24	188	246
503—Wichita River at Wichita Falls, Tex	25	324	288
507—Red River near Terral, Okla	24	2,567	2,420
508—Red River near Gainesville, Tex	26	3,168	2,820
520—Washita River near Durwood, Okla	34	1,526	1,245
522—Red River near Colbert, Okla. (Denison Dam)	39	5,201	4,320
526—Clear Boggy Creek near Caney, Okla	20	497	321
527—Red River at Arthur City, Tex	32	8,672	7,090
529—Red River at Index, Ark	26	12,680	10,600
700—Beaver Creek near Waurika, Okla	9	152	164
703—Salt Fork of Red River near Wellington, Tex	10	87	89
704—Little Wichita River near Henrietta, Tex	9	134	79

*Source: Geological Survey (*15*).

1961 and 1962 (October 1960–September 1962), for each monitoring station, are shown on figures 5 and 6, while average loads for the same period, in tons per day, are shown on figures 7 and 8.

Four reservoirs (three in the Red River system and one in the Arksansas River system) affecting water quality were included in the monitoring network. Inflow into each reservoir differed from the outflow, both in amount and quality and also represented different periods of time. Because capacity in each reservoir equaled or exceeded the average annual streamflow into the reservoir, the time required for flow through each reservoir was a year or more.

Also, because rainfall may be greater or less than evaporation, reservoir outflow might also be either more or less than inflow. To illustrate, the Great Salt Plains Reservoir (Arkansas River Basin) contained 17,000 acre-feet less water on September 30, 1962, than on October 1, 1960, when the study started; Lake Kemp contained 73,000 acre-feet more; and Lake Texoma on the Red River, 109,000 acre-feet more. Detention and mixing in the reservoirs eliminated the effects of sharp upstream variations in quality. Below the reservoirs, the quality has tended to be more uniform.

The weighted average chloride concentration of the Arkansas River at Tulsa exceeded 250 mg./1. However, large quantities of water had a lower chloride concentration during brief periods of very high flow rates. This was also true of the Red River above Gainesville, Tex. Tables 4 and 5 show the changes in water quality in terms of specific conductance as related to acre-feet and percent of the total quantity.

Table 4 indicates that, for the water year from October 1961 to September 1962, 90 percent of the total flow or 22.2 million acre-feet of water in the Arkansas River at Van Buren, Ark., was of acceptable quality, as indicated by an average specific conductance of 1,000 micromhos or less. In the Red River at Index, Ark., for the same period, table 5 shows that 55 percent or 4.5 million acre-feet was of acceptable quality (i.e., 1,000 micromhos or less). While the relationship varies from stream to stream, during the study in the Arkansas-Red River Basins area 1,000 micromhos water represented a chloride content between extremes of 44 and 361 mg./1 as Cl and a dissolved solids content from 560 to 850 mg./1. A chloride concentration of 250 mg./1 or less was indicated by a specific conductance of 1,000 micromhos at 90 percent of the stations.

From these data it appears that there is an abundance of water of acceptable quality available. However, under present conditions 80 to 90 percent of the streamflow for the entire year may pass Van Buren and Index, Ark., in a single 2- to 4-month period, with 10 to 20 percent being distributed over the remaining 8 to 10 months. Therefore, during the major portions of each year, the quality may be unsatisfactory. One problem is to make an abundance of water of acceptable quality available when and where it is needed.

Natural Salt Sources

Field investigations and monitoring stations data show that there are 15 primary natural salt

TABLE 5.—Red River Basin—Selected Stations—Quantity and Percentage of Water of Various Qualities (Oct. 1960–Sept. 1962)

Station number, stream and location	Total flow (acre-feet)	Acre-feet of water (and % of total) of following specific conductance, micromhos/cm*							
		0–500	500–1,000	1,000–1,500	1,500–2,500	2,500–5,000	5,000–10,000	10,000–30,000	>30,000
Oct. 1960–Sept. 1961 (Water Year 1961)									
478—Red River near Brice, Tex.	63,000	0 0.0%	0 0.0%	0 0.0%	29,100 46.2%	24,100 38.3%	4,550 7.2%	5,090 8.1%	136 0.2%
481—Salt Fork Red River near Mangum, Okla.	122,400	100 0.1%	51,300 41.8%	14,600 12.0%	36,700 30.0%	19,700 16.1%	15 0.0%	0 0.0%	0 0.0%
490—North Fork Red River near Headrick, Okla.	427,100	0 0.0%	26,300 6.1%	121,700 28.5%	129,400 30.3%	117,500 27.5%	31,900 7.5%	274 0.1%	0 0.0%
503—Wichita River at Wichita Falls, Tex.	298,500	20,700 6.9%	38,500 12.9%	46,900 15.7%	62,500 20.9%	117,800 39.5%	11,800 4.0%	229 0.1%	0 0.0%
507—Red River near Terral, Okla.	1,940,000	0 0.0%	61,300 3.2%	172,700 8.9%	850,400 43.8%	621,100 32.0%	234,600 12.1%	0 0.0%	0 0.0%
508—Red River near Gainesville, Tex.	2,204,000	0 0.0%	40,700 1.8%	155,100 7.0%	1,057,000 48.0%	682,600 31.0%	268,300 12.2%	0 0.0%	0 0.0%
520—Washita River near Durwood, Okla.	819,800	271,400 33.1%	345,300 42.1%	196,300 24.0%	6,830 0.8%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
522—Red River near Colbert, Okla.	2,941,000	0 0.0%	0 0.0%	0 0.0%	2,935,000 99.8%	6,370 0.2%	0 0.0%	0 0.0%	0 0.0%
529—Red River at Index, Ark.	7,318,000	1,920,000 26.2%	2,113,000 28.9%	1,502,000 20.5%	1,783,000 24.4%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
750—Red River near Quanah, Tex.	204,600	0 0.0%	0 0.0%	687 0.3%	1,750 0.9%	94,200 46.0%	52,300 25.6%	55,600 27.2%	0 0.0%
752—Wichita River below Lake Kemp, Tex.	162,000	0 0.0%	4 0.0%	4 0.0%	28 0.0%	162,000 100.0%	0 0.0%	0 0.0%	0 0.0%
Oct. 1961–Sept. 1962 (Water Year 1962)									
478—Red River near Brice, Tex.	40,300	0 0.0%	0 0.0%	0 0.0%	42 0.1%	22,700 56.3%	15,700 39.0%	1,800 4.5%	27 0.1%
481—Salt Fork Red River near Mangum, Okla.	57,800	273 0.5%	8,030 13.9%	16,800 29.1%	24,200 41.8%	8,500 14.7%	0 0.0%	0 0.0%	0 0.0%
490—North Fork Red River near Headrick, Okla.	307,100	7,420 2.4%	26,500 8.7%	71,700 23.3%	116,300 37.9%	39,200 12.8%	45,000 14.6%	1,030 0.3%	0 0.0%
503—Wichita River at Wichita Falls, Tex.	116,900	0 0.0%	8,600 7.4%	15,900 13.6%	19,900 17.1%	46,200 39.5%	26,000 22.2%	257 0.2%	0 0.0%
507—Red River near Terral, Okla.	1,556,000	0 0.0%	121,100 7.8%	455,200 29.2%	412,100 26.5%	514,800 33.1%	52,300 3.4%	0 0.0%	0 0.0%
508—Red River near Gainesville, Tex.	1,874,000	0 0.0%	201,900 10.7%	686,200 36.6%	398,500 21.3%	564,400 30.2%	23,000 1.2%	0 0.0%	0 0.0%
520—Washita River near Durwood, Okla.	976,800	297,100 30.4%	388,500 39.8%	250,900 25.7%	40,300 4.1%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
522—Red River near Colbert, Okla.	3,137,000	0 0.0%	0 0.0%	0 0.0%	3,137,000 100.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
529—Red River at Index, Ark.	7,912,000	2,299,600 29.1%	2,188,100 27.7%	1,475,300 18.6%	1,949,300 24.6%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
750—Red River near Quanah, Tex.	136,100	0 0.0%	0 0.0%	0 0.0%	119 0.1%	24,000 17.6%	68,800 50.6%	41,500 30.5%	1,650 1.2%
752—Wichita River below Lake Kemp, Tex.	84,100	0 0.0%	2 0.0%	4 0.0%	22 0.0%	84,000 99.9%	108 0.1%	0 0.0%	0 0.0%

*Average of all waters below 1,000 micromhos/cm conductance, when combined, is considered to meet Public Health Service drinking water standards.

sources with a total daily salt emission of approximately 13,000 tons per day as sodium chloride. As shown in table 6, and illustrated on figure 9, 10 of these sources are in the Red River Basin and 5 in the Arkansas River Basin.

Geological studies of the Ground Water Branch of the Geological Survey show that these salt waters are relatively young and that the phenomenon of fresh water percolating downward through formations containing salt and its eventual reappearance as brine occurs within an area of a 10-mile radius or less. During dry weather the brines may evaporate or flow underground shortly after they reach the streambeds. Figure 10 is an idealized sketch of the brine generation and emission phenomenon, based upon the Geological Survey findings (*16*).

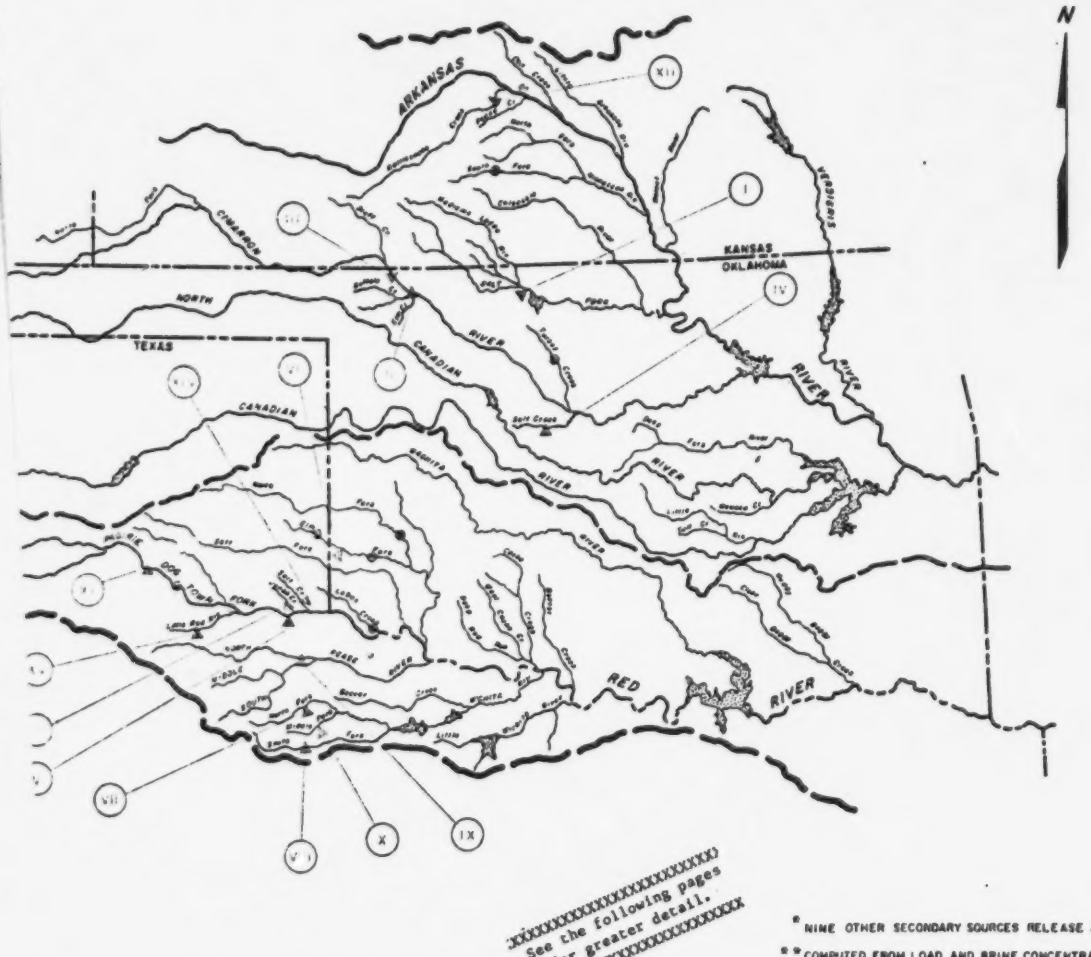
The emission rate of many of the natural brines was difficult to determine or predict. Some natural brineflows appear to vary directly with the rainfall and stream variations. Large amounts of solid salt have accumulated in the vicinity of and below these sources. Examples are the 10,000-acre Great Salt Plains (Area I) in Oklahoma; the broad, 4-mile-long salt flats of the Big Salt Plains in the Cimarron River streambed in Oklahoma (Area II); and the 25-mile salt plain which develops on the Little Red River in Texas (Area XV) during dry weather.

Table 7 lists seven additional natural mineral-pollution sources that were found from load balances of the monitoring network results and from conferences with State officials. These sources are classified as secondary because their brines do not have an

TABLE 6.—Major Natural Sources of Brine

Map* area No.	Salt source area	Identifying community	Description Type emission, extent, size	Approximate concentration of brine as Cl (mg./l)
	Arkansas River Basin			
II	Big Salt Plains, Okla.	Edith, Okla.	About 4-mile stretch of Cimarron River (1 mile along Buffalo Creek.) Densely encrusted salt plains up to 2 miles wide. Numerous small springs and seeps (less than 5 g.p.m.). Substantial surface flows of brine at lower end of area.	190,000
I	Great Salt Plains, Okla.	Cherokee, Okla.	10,000-acre salt flat immediately above Great Salt Plains Reservoir; saturated brine about 1½ feet below ground surface at edge of salt flat. Brine may flow on surface at edges of reservoir and into reservoir underwater.	190,000
III	Little Salt Plains, Okla.	Buffalo, Okla.	Similar to Area II. Plain about 2 miles long, and up to 1 mile wide.	190,000
IV	Salt Creek, Okla.	Southard, Okla.	Numerous small brine springs at base of 300-foot canyon at upper end of creek.	60,000
XII	Rattlesnake Creek, Kans.	Raymond, Kans.	Numerous small seeps into two saltwater marshes and along bed of Rattlesnake Creek.	11,000
	Red River Basin			
V	Estelline Spring, Tex.	Estelline, Tex.	Large 5 cfs (3 million gals/day) spring 75-foot diameter at surface. Flow constant, 1959–62.	25,000
VI	Elm Fork, Okla.	Carl, Okla.	Numerous seeps and small springs near mouths of three canyon streams (tributaries to Elm Fork of Red River) about 1 mile apart.	190,000
VII	North Fork, Wichita River, Tex.	Paducah, Tex.	Several large springs, numerous seeps and salt plains, mostly on 2-mile stretch above mouth of Salt Creek of North Wichita River.	20,000
VIII	South Fork, Wichita River, Tex.	Guthrie, Tex.	Several large springs and numerous seeps along 2-mile stretch on South Wichita River.	4,000–27,000
IX	Middle and North Fork, Pease River, Tex.	Childress, Tex.	Numerous seeps along 2-mile stretches of both North Pease and Middle Pease Rivers.	10,000–20,000
X	Middle Fork, Wichita River, Tex.	Paducah, Tex.	One large spring and several small seeps along 2-mile stretch of Middle Wichita River.	2,000–4,000
XI	Prairie Dog Town Fork, Tex.	Brice, Tex.	Numerous brine seep areas along Prairie Dog Town Fork of Red River, mostly at mouths of tributary streams.	4,000–32,000
XIII	Jonah Creek, Tex.	Childress, Tex.	Salt plains, one large and numerous small brine springs in streambed along edge of Jonah Creek for a 3-mile stretch above mouth.	27,000–40,000
XIV	Salt Creek, Tex.	Childress, Tex.	Numerous small seeps in streambed along 2-mile stretch above mouth.	30,000
XV	Little Red River, Tex.	Turkey, Tex.	Numerous small seeps and springs in streambed at upper end of Little Red River for about 1-mile stretch of both North and South branches.	100,000–150,000

*See figure 2.



VICINITY MAP

SIGNIFICANT * NATURAL BRINE EMISSION AREAS

AREA NO	LOAD - TONS/DAY, AVERAGE (Load computed from 1961-62 Water Years Study)		ESTIMATED CONCENTRATED BRINE FLOW ** (CFS)
	As Chloride	As Salt (NaCl)	
I	1400	2310	5
II	2950	4960	10
III	600	990	2
IV	220	360	1
V	375	620	5
VI	250	410	1
VII	200	330	2
VIII	200	330	2
IX	350	580	2
X	50	80	1
XI	175	290	2
XII	200	330	2
XIII	450	740	4
XIV	150	250	2
XV	150	250	1

XXXXXXXXXXXXXXXXXXXXX
See the following pages
for greater detail.
XXXXXXXXXXXXXXXXXXXXX

* NINE OTHER SECONDARY SOURCES RELEASE ABOUT 1,060 TONS CHLORIDE/DAY.

** COMPUTED FROM LOAD AND BRINE CONCENTRATION

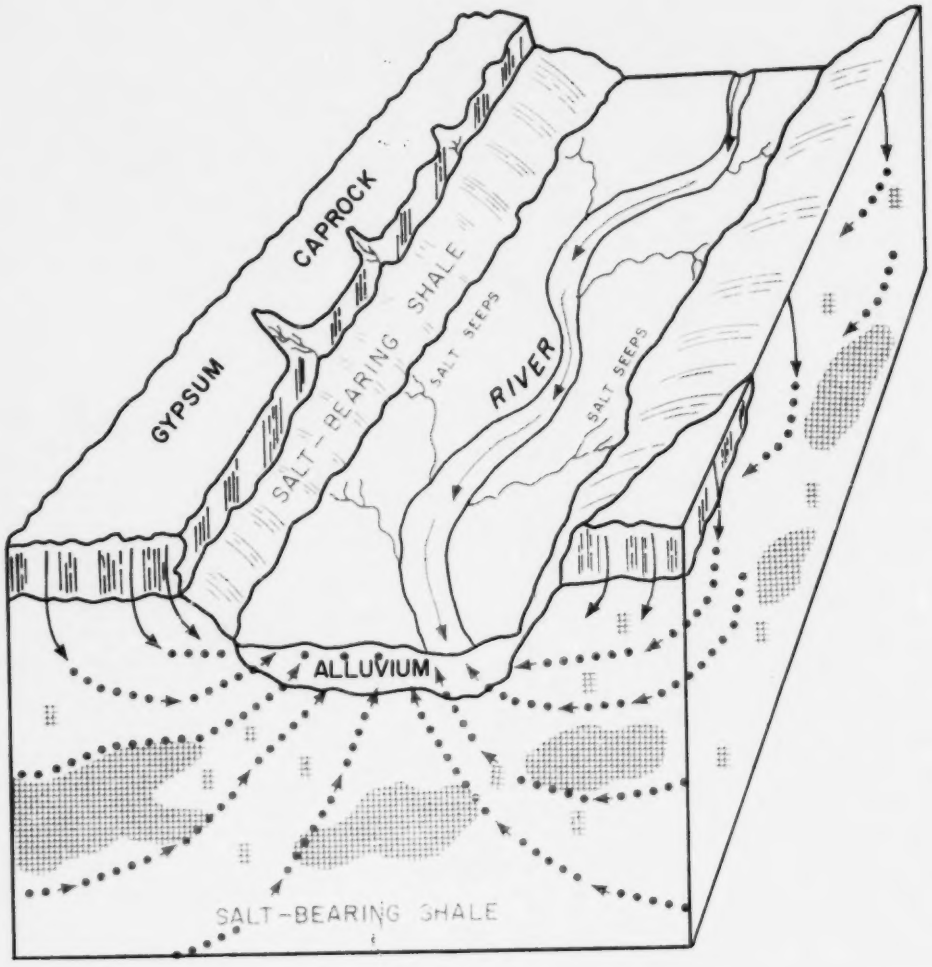
▲ SIGNIFICANT NATURAL BRINE EMISSION AREA

● SECONDARY NATURAL BRINE EMISSION AREA

ARKANSAS–RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

LOCATION OF NATURAL BRINE EMISSIONS 20

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS



LEGEND

BEDDED SALT

DISSEMINATED SALT

FRESH GROUND WATER

SALTY GROUND WATER

ARKANSAS-RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

IDEALIZED SKETCH OF GROUND WATER MOVEMENT AND ACTION ON SALT-BEARING FORMATIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

765-197 O - 65 (Face p. 12) No. 9

FIGURE 10

excessively degrading effect. Two additional presumed natural sources are shown in table 7. The total salt loads of these nine pollution sources, as sodium chloride, are 800 tons per day in the Arkansas River Basin and 940 tons per day in the Red River system. Several of these sources, particularly those in the Arkansas near Great Bend, Kans.; the Ninnescah near Cairo, Kans.; and above and below the three canyon streams, tributary to Elm Fork of Red River (Area VI) will be investigated in more detail.

Although further study may add other pollution sources to this category, it is believed that the 15 primary sources are the most significant and that their control or elimination will provide maximum water quality improvement. If, for example, the five major salt sources in the Arkansas River are eliminated, about 8,950 tons of salt per day will no longer be discharged into the river. At an average annual streamflow of 6,700 cfs at Tulsa, Okla., chloride concentrations will be reduced by 320 mg./1, leaving about 150 mg./1 of chloride from other sources. In the Red River Basin, elimination of all 10 primary salt sources will reduce the salt loading by 3,880 tons per day and lower the chloride concentration at average flows by 150 mg./1, leaving 200 mg./1 from other sources. Figures 11 and 12 show the estimated effect on chloride concentration of elimination of the major natural sources of mineral pollution.

TABLE 7.—Secondary Natural Brine Sources

	General location	Estimated salt load tons NaCl/day
Arkansas River	Ninnescah River (Kans.)	350
	Turkey Creek (Cimarron River, Okla.).	50
	Arkansas River and tributaries between Great Bend and Hutchinson.*	400
	Total	800
Red River	Red River and tributaries between Area XI and Estelline, Tex.	80
	Lebos Creek downstream from Eldorado, Okla.	80
	Elm Fork of Red River, immediately above Area VI.	160
	Elm Fork of Red River and tributaries downstream from Area VI.**	400
	Boggy Creek of North Fork of Red River.	20
	Below Area XI (additional)*	200
	Total	940

*Presumed source—located (general) and estimated on basis of stream monitoring network load balance.
**100 T/D secondary and 300 T/D presumed.

Calcium and sulfate are added to the streams by the passage of water over and through the large surface and subsurface deposits of gypsum (calcium sulfate) in the area. Figure 3 shows the locations of surface outcrops of gypsum and of the subsurface deposits of salt.

In general, in these basins, sulfate concentrations are lower than chlorides and are less objectionable. Methods similar to those for chloride control cannot now be suggested for appreciable sulfate reduction and should be the subject of further research. Estimates are that procedures which reduce natural and manmade mineral pollution will provide at least a 5 percent reduction in sulfates. The final sulfate concentrations will place no serious limitations on water use.

Manmade Brine Sources

Brine from oil and gas production accounts for over 90 percent of the manmade load. Table 8 shows the magnitude of this waste disposal problem, and Figure 2 shows the area covered by this industry.

TABLE 8.—Oil Brine Production and Reinjection, Arkansas and Red River Basins

	Kansas	Oklahoma	Texas
Oil production (1960) (mil. bbls.)	100	200	150
Total brine production/day* (mil. bbls.)	2.54	• 1.5	• .6
Estimated chloride in brine* (tons/day)	36,700	• 50,000	• 25,000
Brine to pit or direct to stream*:			
Bbls./day	3,000	(**)	(**)
Tons/day	120	(**)	(**)
Percent reinjected*	99.7	95+	95+

• Estimated.
*Information obtained from State agencies.
**Information not available.

The portions of Kansas, Oklahoma, and Texas in the Arkansas-Red River Basins produce about 17 percent of the United States oil. For each barrel of oil, as much as 100 barrels of salt water may be produced with concentrations ranging from a few thousand milligrams per liter to 200,000 mg./1 of chloride (*17*). The potential load is enormous and the dedicated work of State and local agencies together with the cooperation of petroleum producers has resulted in the reinjection of an estimated 95

percent of the oilfield brines. However, the residual 5 percent is troublesome and should be brought under control.

Streams such as the Verdigris River in Kansas and Oklahoma, Walnut River in Kansas, and Little Wichita in Texas appear to contain mostly man-made brines. During this study as shown on figures 5 and 6, the average dissolved solids concentrations in these streams were less than 500 mg./1.

Other industrial sources of salt waste (other than gas and oil production) are four salt plants and a chemical plant which uses underground salt. The salt load from these industries is estimated as 70 tons per day average (1963) by the Kansas Board of Health.

Liquefied petroleum gas storage operations are a potential source of salt water. These storage caverns are leached in salt beds and the saturated brine is used to displace or remove the liquefied petroleum gas. Losses during construction and operation are reported to be minor.

Many activities produce salt as a waterborne waste. Salt used for domestic purposes and in the regeneration of water softeners is carried out in sewage, but it is a minor portion of the total salt load. The total salt waste load from municipal and domestic activities is estimated to average less than 3 percent of the total salt load measured at the lowermost stations.

It was recently estimated that more than 1 million tons of livestock salt was used in the United States. With 8.1 percent of the U.S. livestock pastured in these basins, it is assumed that a portion of this salt is washed off into basin streams.

Water Quality Objectives

Advance planning for water quality control in the Arkansas-Red River Basins, including cost estimates, depends on the extent to which the mineral pollutants in these streams are to be eliminated. Water quality objectives are needed which are realistic in terms of needs and capable of fulfillment at a reasonable cost. Because sodium chloride is the major mineral pollutant, chloride concentration has been selected as an indication of water quality in these basins. Elimination or reduction of the sources of chloride pollution will also affect a reduction in the amount of sulfate and dissolved solids in the basins' streams.

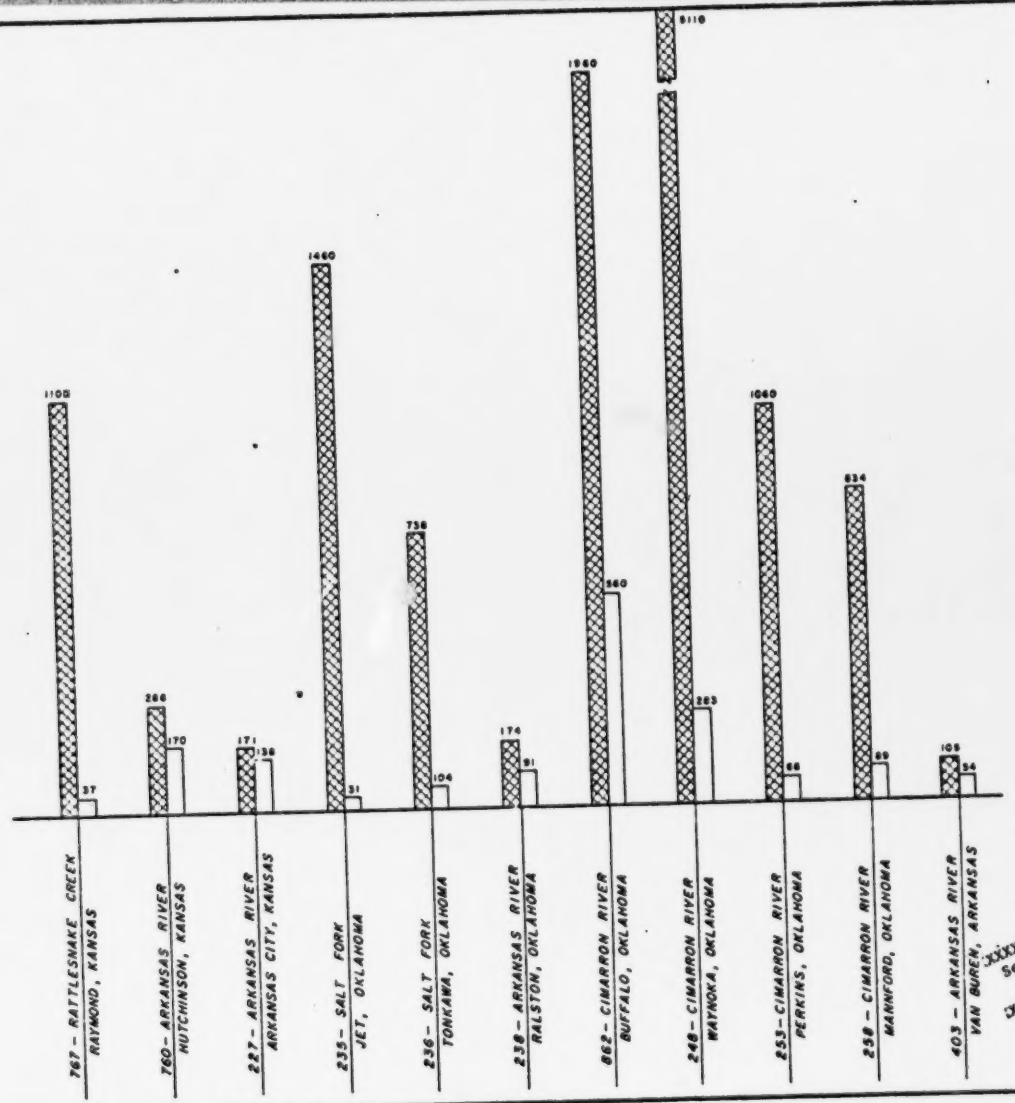
According to the Public Health Service Drinking Water Standards, 1962, in use by State agencies of the Arkansas-Red River Basins, the presence in drinking water of either chlorides or sulfates in excess of 250 mg./1 is unacceptable, if other more suitable supplies are or can be made available (*18*). However, this standard does not meet the requirements of all the water uses shown in table 9. The quantities shown are those at which impairment has been found and a lower concentration is usually desirable. A chloride concentration of 100 mg./1 is considered as desirable in meeting the needs of most uses listed in table 9.

Local and State officials have indicated that mineral concentrations should be reduced as much as possible to afford maximum development opportunities to industries requiring high quality water. The ultimate objective is a reduction in the salt loads of the entire river systems. This would encourage economic development uniformly throughout the basins, other factors being equal.

TABLE 9.—Chloride Concentration-Use Spectrum

Use	Concentration (mg./1)
Stock and wildlife	1,500
Food canning and freezing	760
Domestic water supply	250
Carbonated beverages	250
Food equipment washing	250
Irrigation (19)	250
Paper manufacturing, kraft pulp	200
Steel making	175
Textile process	100
Brewing	80
Paper manufacturing, soda pulp	75
Paper manufacturing, ground wood pulp	75

Source: California Water Pollution Control Board (*20*).



NOTE

1. ONLY THOSE STATIONS WHERE WATER QUALITY WILL BE AFFECTED ARE SHOWN.
2. STATION NUMBER AND NAME OF NEAREST COMMUNITY, AS WELL AS STREAM MONITORED ARE SHOWN FOR EACH QUALITY SURVEILLANCE STATION.
3. CHLORIDES CONCENTRATIONS WERE COMPUTED FROM CONTINUOUS SPECIFIC CONDUCTANCE MEASUREMENTS AND ARE FLOW WEIGHTED AVERAGES FOR 1961–1962 WATER YEARS (OCT. 1960 – SEPT. 1962). CONDUCTANCE WAS NOT OBTAINED FOR ENTIRE FLOW.
4. ALL CHLORIDES CONCENTRATIONS IN MILLIGRAMS PER LITER, mg/l.
5. ALL CHLORIDES CONCENTRATIONS ARE BASED UPON DATA COLLECTED DURING TWO-YEAR PERIOD OF INTENSIVE STUDY AND ASSUMING COMPLETE CONTROL OF THE 15 MAJOR NATURAL POLLUTION SOURCES (SEE FIG. 9).

WITHOUT ELIMINATION OF NATURAL BRINES

WITH ELIMINATION OF NATURAL BRINES.

See the following pages for greater detail.

ARKANSAS–RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

ESTIMATED EFFECT OF ELIMINATION OF NATURAL BRINE EMISSIONS ON CHLORIDES CONCENTRATIONS
ARKANSAS RIVER AND TRIBUTARIES

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 11

Proposals for the Control of Mineral Pollution

Natural brine emissions located and defined in this report, together with oilfield brines, contribute an estimated 95 percent of the mineral pollution in the Arkansas-Red River Basins. It is estimated that this pollution is carried in considerably less than 1 percent of the average flow of the affected streams shown on figure 13. Control of natural and oilfield brine pollution will be required to achieve the chloride concentration objective of 100 mg./1 or less in the stream reaches where use is expected to develop.

Natural Mineral Pollution Reduction

Numerous procedures have been suggested for the elimination or reduction of natural brineflows reaching the streams in these basins involving engineering works such as dams, dikes, storage basins, canals, and pumping systems for the collection, storage, suppression, and transmission of the natural brines. Although engineering and design practices are well advanced for water resource development projects, the control of large volumes of brines is unique and untried.

The Corps of Engineers is studying brine-control methods and field testing one of those proposed. The following broadly classified proposed methods (either alone or in combination) will be studied.

Subsurface Disposal of Brines

Most brines from oil and gas production in these basins are currently reinjected into the formations from which the oil and gas have been extracted. Similar subsurface disposal of natural brines may be possible; if suitable geological formations underlie, or are not too distant from, natural brine sources, and the volume of the brines is not too great, such disposal may be satisfactory.

The University of Oklahoma conducted a preliminary study of the potential for subsurface disposal of natural brines in both basins. It was concluded that this method offers promise; receptive subsurface strata of large capacity are available and disposal costs seem reasonable. Table 10 summarizes the pertinent data and costs estimated for injection equipment, operation, well drilling, and the capacity of subsurface formations. The actual costs of this method of disposal can only be determined by field tests at each site. The disposal areas considered are within a 20-mile radius of the salt source. Although the study was limited to shallow strata, about 5,000 feet deep ,the desirability of investigating deeper strata in the southwestern portions of the basins was recognized (*21*).

James A. Lewis Engineering, Inc., of Dallas, made a preliminary investigation for the Public

TABLE 10.—Natural Brine Disposal Cost Estimates by Subsurface Injections* (Includes all capital, amortization, and operation costs)

Area and Brine Source	Brine volume (cfs)	Chloride tons/day	Number of disposal wells	Years storage (est.)	Cost per million gallons	Cost per barrel (42 gal.) (Cents)	Chloride cost per ton ($)	Total annual cost ($1,000)
I—Great Salt Plains	5	1,400	13	80–160	$445	1.8	0.90–1.81	460–925
II and III—Big Salt Plains and Little Salt Plains	12	3,550	6	200–300	448	1.8	.22–0.35	285–454
IV—Salt Creek of Cimarron River	1	220	1	2,700	426	1.7	1.38	111
V—Estelline Spring	5	375	5	750	533	2.2	3.97	543
VI—Elm Fork Springs	1	250	4	1,000	415	1.7	.90	82.1
VII, IX, and X—North Wichita River, Middle Wichita River and Pease River	5	450	4	1,000	550	2.3	4.77	783
VIII—South Wichita River	2	200	4	250	502	2.1	8.70	635

*Exclusive of collection and concentration, if required.

Source: Based on a study for the Public Health Service by the University of Oklahoma. (*21*)

Health Service of the potential for subsurface disposal of natural brines into deep formations in the upper Red River Basin. Attention was directed mainly to the Arbuckle (or Ellenburger) formation underlying portions of Kansas and northern Oklahoma which has great receptive capacity. It was concluded that this method has promise for some areas but that more basic information is needed (22).

Permanent Storage-Retention of Natural Brines

Brines can be collected and retained in off-channel storage, as in the case of the Great Salt Plains. Here, fresh water upstream from the plains could be diverted around the plains to the downstream side of the reservoir. Brines would be stored in the Great Salt Plains Reservoir and an alternate means of flood control would have to be found. It is estimated that the reservoir with minor modifications has a brine-storage capacity of 100 years or more at the present rate of brine emission. The rate of brine emission may well lessen as the depth of stored brine increases, thus increasing the hydrostatic head.

Elimination or Reduction of Fresh Recharge Waters to Subsurface Salt Deposits

Part of the rainfall goes into the ground and percolates slowly downward through porous rocks and soils. When this underground water comes in contact with salt deposits, part of the salt is dissolved and forms a concentrated brine which may appear as a salt spring or seep at the ground surface. If the flow of fresh water can be eliminated, or its direction of flow changed so that it no longer dissolves salt or has sufficient head to reach the ground surface, this source of brine can be controlled.

Elimination or Reduction of Brine Flows by Hydrostatic Pressure

Natural brine springs are hydrologic phenomena which appear to have a low static head or driving force. Inundation (or plugging of large single springs) may impose enough back pressure to stop or reduce the brine flow. The Corps of Engineers is currently conducting two tests to ascertain the practicability of this method and to obtain basic data on the effects of such inundations on the hydrologic environment. The tests will include a dike around Estelline Springs (Area V) to impose a static head of about 6 feet on the spring, and the imposition of a 6- to 10-foot hydrostatic head on a large spring on the South Wichita River (Area VIII).

Transportation to Nondamaging Disposal Site

Accumulated stored brines, as well as brines at each source, may be collected and transported with wastes by pipelines or canal to areas with large assimilation capacity such as the Gulf of Mexico.

Utilization of Salt

Answers from inquiries to the Chlorine Institute, Salt Institute, and other large individual salt producers and users indicate that increased utilization of salt is only a remote possibility. An increase in present-day demands and/or process may stimulate removal, but the amount extracted will be only a small portion of that discharged.

About 3,000 tons of salt per day are produced from underground deposits, mostly in the Hutchinson area in Kansas. It may be feasible to replace this salt with natural brine from Big Salt Plains (Area II) and Little Salt Plains (Area III) about 120 miles away on the Cimarron River in Oklahoma. The collection system and pipeline to the existing saltworks could be constructed and operated by the pollution abatement agency.

The solid salt from these sources is similar in quality to that produced in the Hutchinson salt plants where the salt is about 97 percent NaCl, about 2.5 percent $CaSO_4$, and the remainder magnesium, chlorides, sulfates, and inerts. Salt from the Great Salt Plains has about the same analysis; weaker brines from other areas contain up to 10 percent $CaSO_4$.

Alternate Supplies and Blending

Sufficiently improved quality may be realized by transferring and blending high quality waters from the eastern part of the basins with those of high mineral content in the central basins. If eastern waters are available for transfer at an early date, a blending plan would increase the total volume of usable water.

COLORADO SPRINGS
PUEBLO
ARKANSAS
Rattlesnake Creek
COLORADO
NEW MEXICO
CIMARRON
NORTH
TEXAS
Buffalo Cr.
Elm Cr.
Salt Fork
CANADIAN
RIVER
Salt Cr.
CANADIAN
AMARILLO
North Fork
Elm
Salt Fork
WASHITA
PRAIRIE DOG TOWN FORK
Salt Cr.
LAWTON
Little Red Riv.
North Pease River
RED
Middle
South Fork
North Fork
Middle Fk.
Wichita
River
South Fork
WICHITA FALLS
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SCALE IN MILE

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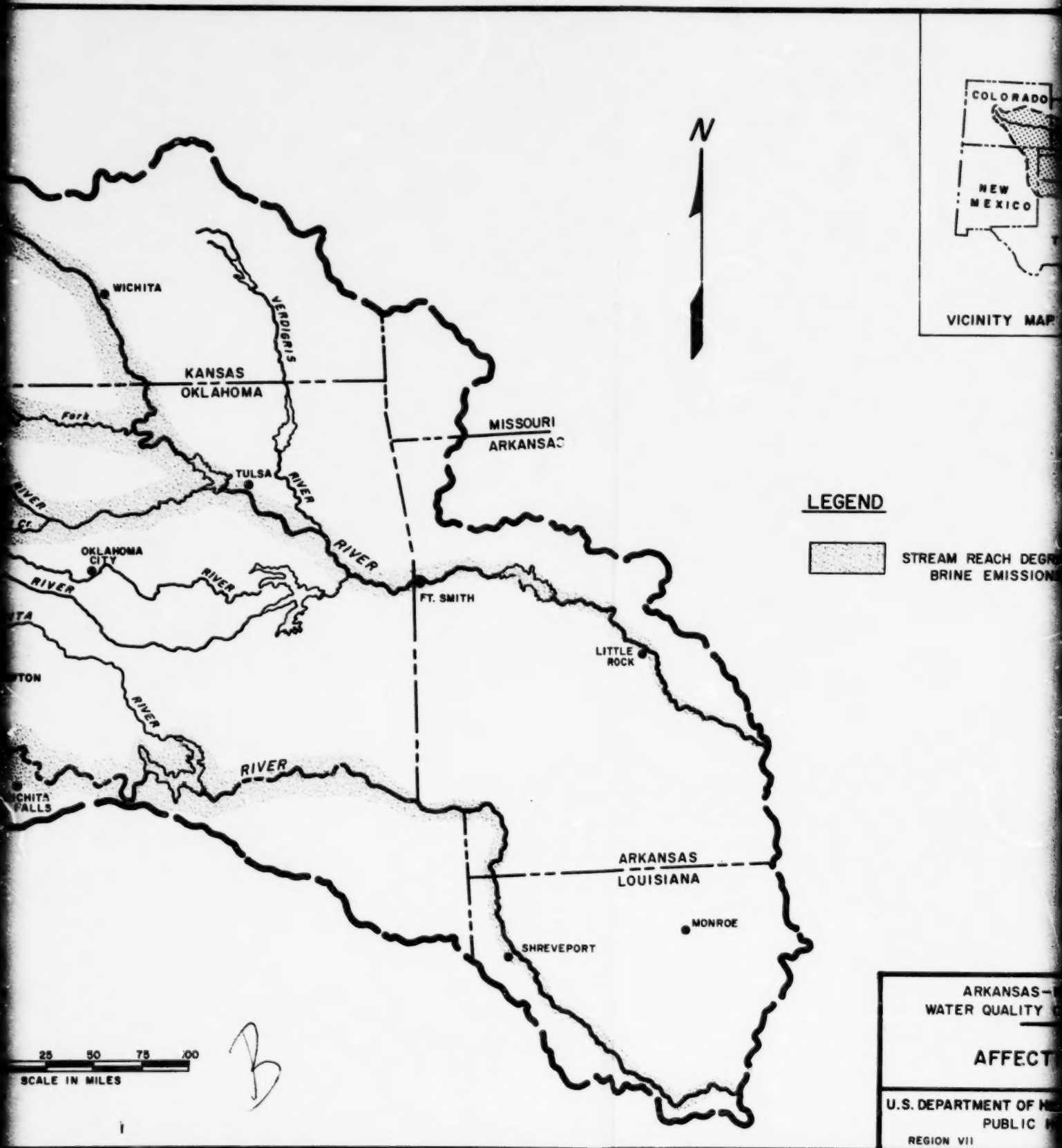
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KANSAS
OKLAHOMA
MISSOURI
ARKANSAS
TULSA
RIVER
OKLAHOMA CITY
FT. SMITH
LITTLE ROCK
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LOUISIANA
MONROE
SHREVEPORT
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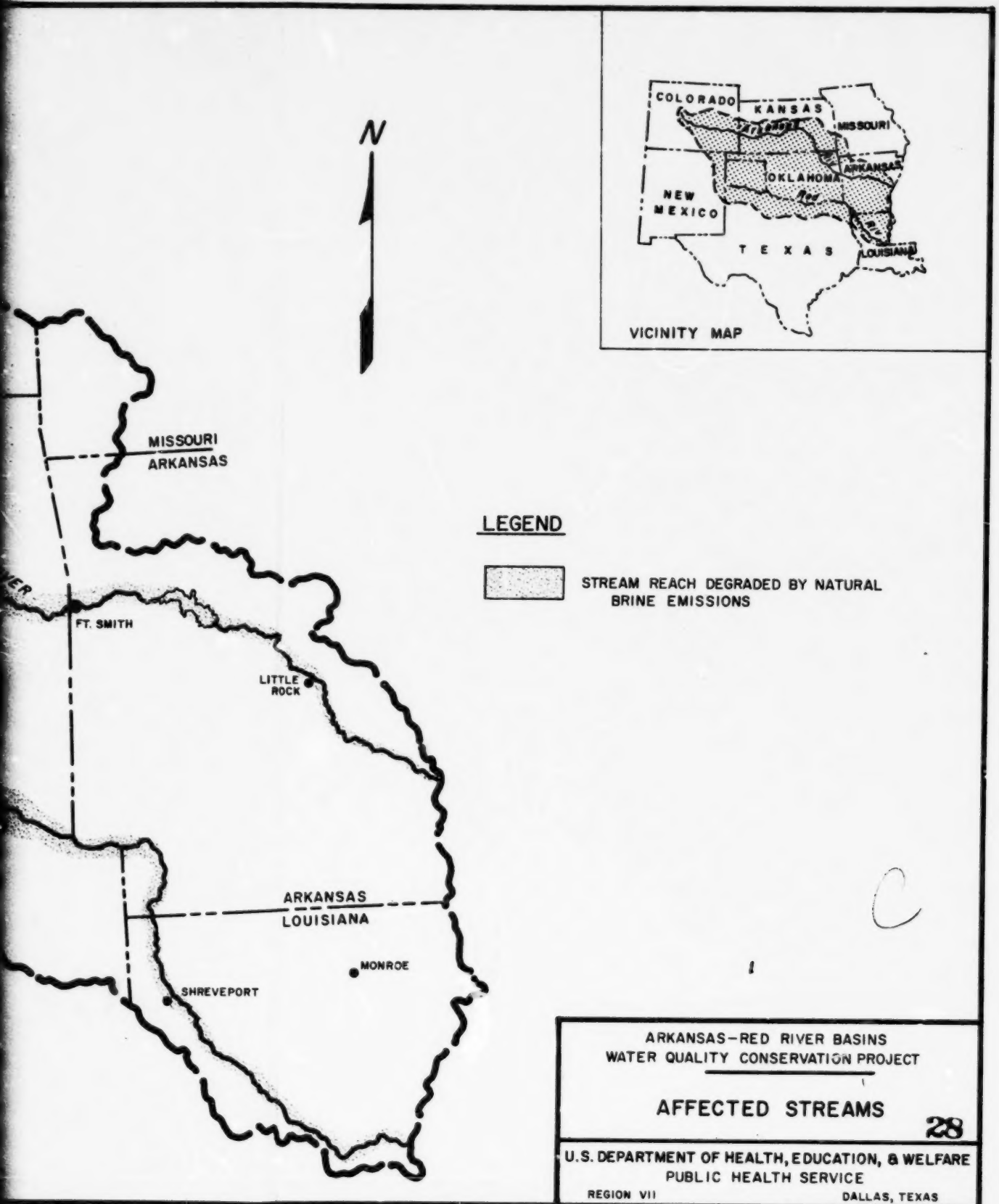
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LEGEND
STREAM REACH DEGRADED BY NATURAL BRINE EMISSIONS
FT. SMITH
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U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
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DALLAS, TEXAS

FIGURE 13

Abatement Program for Natural Salt Pollution

Based on preliminary findings, the greatest potential for improvement in water quality lies in effective control of natural salt sources at the following locations:

1. Sources on the three tributaries of the Wichita River (shown as Areas VII, VIII, and X on fig. 9).
2. The Big and Little Salt Plains on the Cimarron River (shown as Areas II and III on fig. 9).
3. The Great Salt Plains on the Salt Fork of the Arkansas River (shown as Area I on fig. 9).
4. Sources on the Elm Fork of the North Fork of the Red River (shown as Area VI on fig. 9).
5. Estelline Spring (shown as Area V on fig. 9).
6. Jonah Creek (shown as Area XIII on fig. 9).

Criteria used for evaluating the effectiveness of controlling the sources in the order of preference are (1) the urgency of water needs, (2) volume of water improved, and (3) the degree of improvement possible by control of a single source. The larger areas to benefit by this schedule include Wichita Falls, Denison, and Dallas-Fort Worth, Tex.; Shreveport and Alexandria, La.; and Tulsa and Oklahoma City, Okla.

State Water Pollution Control Programs

All the States in these basins have pollution control legislation and administration programs (including oil and gas brines) to control water pollution. In general, the interest and sometimes the legal authority are divided among several State agencies which have a direct interest either in the quality of the water, in the development of the water resources, or in the development and control of an industry whose waste material may degrade the water. In all of these States, there are voluntary and/or legally authorized cooperative and coordinated programs by the agencies involved. Legislative authority in all of the basin States appears adequate.

The improvement and maintenance of satisfactory water quality for maximum usage throughout these basins will require abatement and control of both manmade and natural brines. Suggested pollution control program goals, by State and subbasin areas, are shown in table 11.

TABLE 11.—Suggested Salt Load Reduction Program in Arkansas and Red Rivers (exclusive of primary and secondary salt sources)

State and basin	Subbasin and area	Present (1961–62) salt load*	Load reduction*	Suggested maximum permissible load after control program*
Kansas:				
Arkansas River	Grand Neosho River	165	65	100
	Verdigris River	330	230	100
	Walnut River	455	355	100
	Arkansas River and Tributaries—Great Bend to Arkansas City	850	600	250
Oklahoma:				
Arkansas River	Salt Fork of Arkansas River	350	250	100
	Cimarron River	575	425	150
	Verdigris River	1,330	1,030	300
	Canadian River	2,360	2,060	300
	Arkansas River—Arkansas City, Kansas to Tulsa, Okla	450	300	150
	Arkansas River—Tulsa, Okla. to Van Buren, Ark	845	645	200
Red River	Washita River	265	215	50
	Red River above Lake Texoma	520	470	50
Texas:				
Arkansas River	Canadian River	320	270	50
Red River	Wichita River	360	310	50
	Beaver Creek (Wichita River)	130	105	25
	Red River and Tributaries above Lake Texoma	1,360	1,060	300

*Tons NaCl/day.

Economic Analysis and Benefits

Four factors are involved in the future economic growth prospects of the Arkansas-Red River Basins study area. These factors are (1) the condition of the national economy; (2) the oil and gas and other natural resource situation; (3) the geographic location of the basins; and (4) the development of the water resources of the two large river systems.

The condition of the national economy is best indicated by its growth rate as measured by population, employment, and gross national product. Present indications are that the population of the Nation will reach 502 million by 2020, an increase of 178 percent; employment will reach 197 million, an increase of 186 percent; and the gross national product will reach $4.5 trillion, an increase of 778 percent.* These expectations indicate a thriving national economy in which the Arkansas-Red River Basins will participate. That is, the future prospects of the basins are closely related to national conditions.

Petroleum and natural gas account for 69 percent of the Nation's energy requirements and 67 percent of the Nation's value of mineral fuel. Their potential for the growing petrochemical industry is increasing. In the light of the above factors, the significance of oil and gas in the national economy can hardly be overstated.

The Arkansas-Red River Basins study area produced approximately one-fourth of the Nation's oil and gas in 1960. At the same time, much of the petroleum and natural gas produced in the study area was marketed and refined in other regions (*9, 10*).

Oil and gas production in the future is expected to increase enough to hold its place in the national-demand pattern for fuel increases to provide feedstock for the petrochemical industry. Petrochemical production in the study area is expected to increase more than 600 percent by 2020.

Future years should show more inbasin processing of locally produced gas and oil. This increase would be attributable to expected low-cost navigation transportation and increasing market size in the Midwest. These factors will make the area more competitive and stimulate regional growth in these products.

*These growth indicators are based on projections of the Economic Task Group of the Ad Hoc Water Resources Council staff.

Pulp and paper production of the basins, though of much lesser significance than oil and gas, should increase in volume and percentage of national totals for reasons similar to the oil and gas situation. The effect will be to increase production about 3½ times.

Agriculture in the study area will continue to increase its output in response to regional and national demands for its products. This increase in production will be associated with additional gains in agricultural productivity. By 2020, the study area should be able to triple its output using half the number of workers employed in 1960. Associated with this increased agricultural production will be the need for equipment and fertilizer. Based on agricultural output and expected national and regional population growth, output from the food and kindred products industry is expected to increase about three fold by 2020.

The geographic location of the basins constituted a considerable handicap early in the century since the major concentrations of population and economic activity were far distant. This locational handicap has been greatly reduced by improved transportation manifested by the highway and air transportation routes as well as by the railroad network of the study area. Continued improvement can be expected in the highways and air facilities. The major improvement in the locational situation, however, arises from the southward and westward trend of the national center of population. The center is now at Salem, Marion County, Ill., about 50 miles east of St. Louis, a shift of 45 miles westward since 1950. This shift and its expected continuance is contributing to the growth of population and markets in the basins, particularly of the large urban and metropolitan areas. The shift is also influencing the size of large population centers in proximity to the region, especially in proportion to the rest of the Nation. Much of this new and expected growth is within 1-day's trucking or rail distance from basin centers. Therefore, industrial operations seeking a production and distribution base relatively nearby these new markets of the northern and southern Midwest will look more favorably than in the past on the Arkansas-Red River Basins for sites.

The fourth factor influencing the growth of the basins involves the two river systems themselves. That is, the two major rivers and their tributaries represent an asset in a current condition of less than optimum development. The rivers can be altered in their performance and use to facilitate or enhance economic activities and to provide essential services and benefits. That is, the river systems can be managed to serve specifically determined purposes in accord with a systematic appraisal of their usefulness. A considerable effort in this regard has already been made as manifested by various flood-control structures and reservoirs throughout the area. Also an active pollution control program is underway among the States with Federal participation and assistance. Plans for navigation and further flood control and multiple-purpose structures also indicate acceptance of the objective of major development and management of this river system's assets.

As significant as these efforts are for the future growth of the region, the development and management of the water quality aspects of these river systems on a comprehensive basis are necessary to assure enhancement of their potential.

At this point in the study, only approximations have been made of the future growth in the basins' economy. These approximations are shown as population and labor force projections in table 12.

TABLE 12.—Labor Force and Population Projections for the Study Area—1960 and 2020

Major Industry Group	1960		2020	
	Number *	Percent	Number *	Percent
Agriculture **	311	9	150	1
Mining	90	3	250	3
Manufacturing	567	17	1,900	20
All other employed	2,256	67	6,750	72
Unemployed	144	4	370	4
Total labor force	3,368	100	9,420	100
Population	9,335	...	24,470	.....

*Thousands of people.
**Includes a small number (less than 1 percent) employed by Forestry and Fisheries.

The water requirements for the several components of the future study area economy affected by water quality improvement are shown in table 13.

If the water quality of the two river systems is improved sufficiently to meet these water requirements, the average annual value of the benefits will be $13,076,000 between 1970 and 2070. Table 14 indicates the distribution of the value of the benefits among uses for the two river basins.

TABLE 13.—Total Water Requirements* for Area Affected by Water Quality Improvement—Arkansas-Red River Basins Study Area, 2020 and 2070 (1,000 acre-feet annually)

	Arkansas River Basin and adjoining areas	Red River Basin and adjoining areas	Total
2020			
Municipal and industrial**	1,760	2,493	4,253
Irrigation	200	120	320
Total	1,960	2,613	4,573
2070			
Municipal and industrial**	3,550	4,900	8,450
Irrigation	200	120	320
Total	3,750	5,020	8,770

*Includes current sources of supply.
**Industrial requirement includes cooling water.

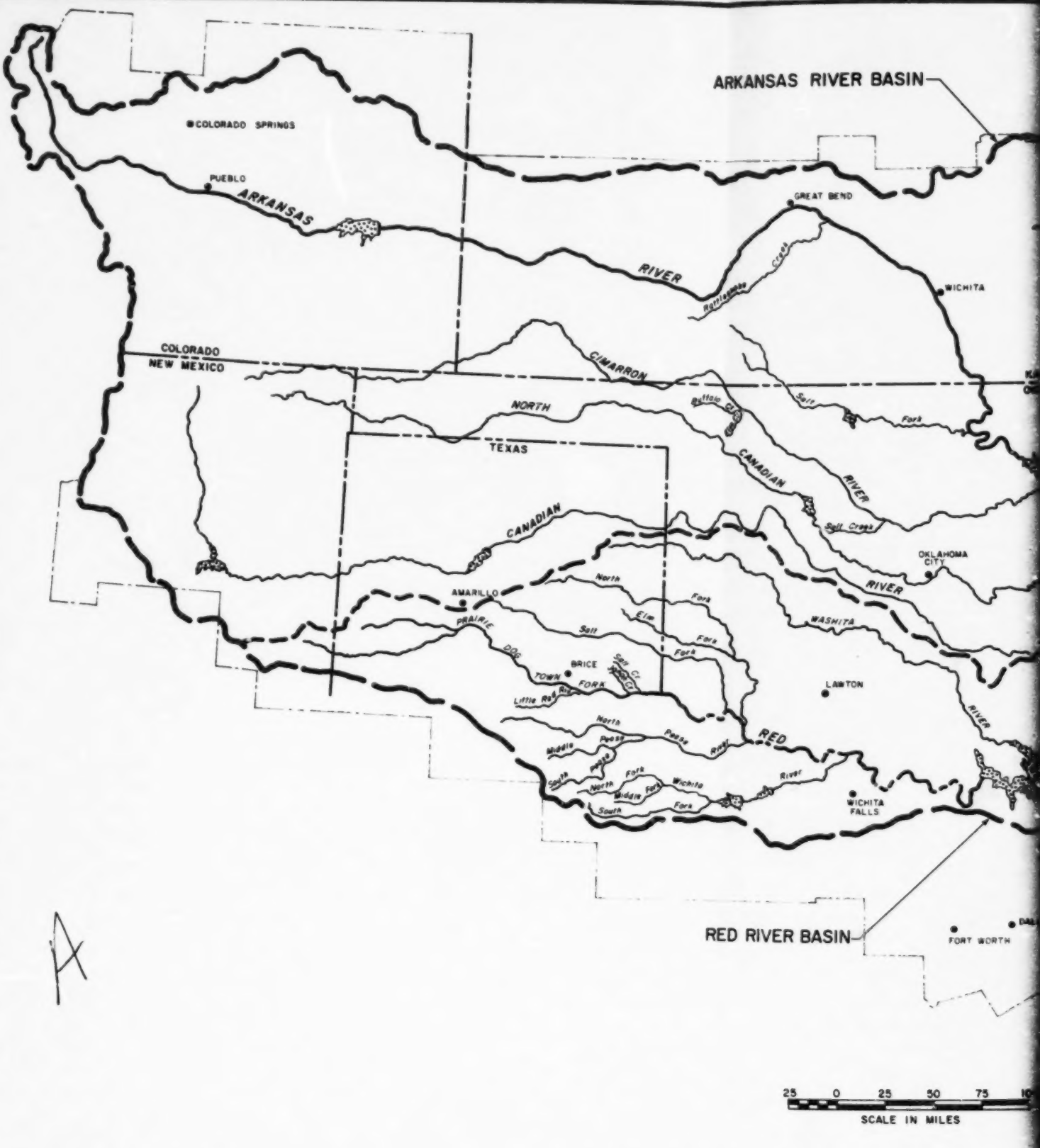
TABLE 14.—Summary of the Value of 1970 to 2070 Benefits—Improvement in Water Quality Arkansas-Red River Basins Study Area

	Average annual value* (1970 worth)		
	Municipal and industrial	Irrigation	Total
Arkansas River Basin and adjoining areas	3,999,000	251,000	4,250,000
Red River Basin and adjoining areas	8,658,000	168,000	8,826,000
Total	12,657,000	419,000	13,076,000

*Over 100 years at 3 percent.

Further study will reveal more clearly the years in which, and the probable location of the areas from which, the water requirements will arise and the stretches of the rivers or their tributaries which must be developed or improved to meet the requirements.

This study should consider information on the cost and effectiveness of natural brine-control measures as it becomes available from the Corps of Engineers. Consideration of alternative measures will also require further study. Stress should be placed on areas of urgent water need and on possible control measures suitable for first attention.


ARKANSAS RIVER BASIN
COLORADO SPRINGS
PUEBLO
ARKANSAS
RIVER
GREAT BEND
Rattlesnake Creek
WICHITA
COLORADO
NEW MEXICO
CIMARRON
NORTH
CANADIAN
RIVER
Buffalo Creek
Salt Fork
TEXAS
Salt Creeks
OKLAHOMA CITY
AMARILLO
North Fork
Elm
Salt Fork
WASHITA
RIVER
PRAIRIE DOG TOWN FORK
BRICE
Salt Cr.
Little Red Riv.
LAWTON
North Pease
Middle Pease
Pease River
RED
RIVER
South Pease
North Fork
Middle Fork
South Fork
Wichita River
WICHITA FALLS
RED RIVER BASIN
FORT WORTH
25 0 25 50 75
SCALE IN MILES

ASIN
N
WICHITA
VERDIGRIS
KANSAS
OKLAHOMA
MISSOURI
ARKANSAS
TULSA
RIVER
ARKANSAS
VAN BUREN
FT SMITH
OKLAHOMA CITY
RIVER
RIVER
LIMIT OF STUDY AREA
LITTLE ROCK
RIVER
RIVER
RIVER
RED
INDEX
TEXARKANA
ARKANSAS
LOUISIANA
DALLAS
FORT WORTH
MONROE
SHREVEPORT
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SCALE IN MILES
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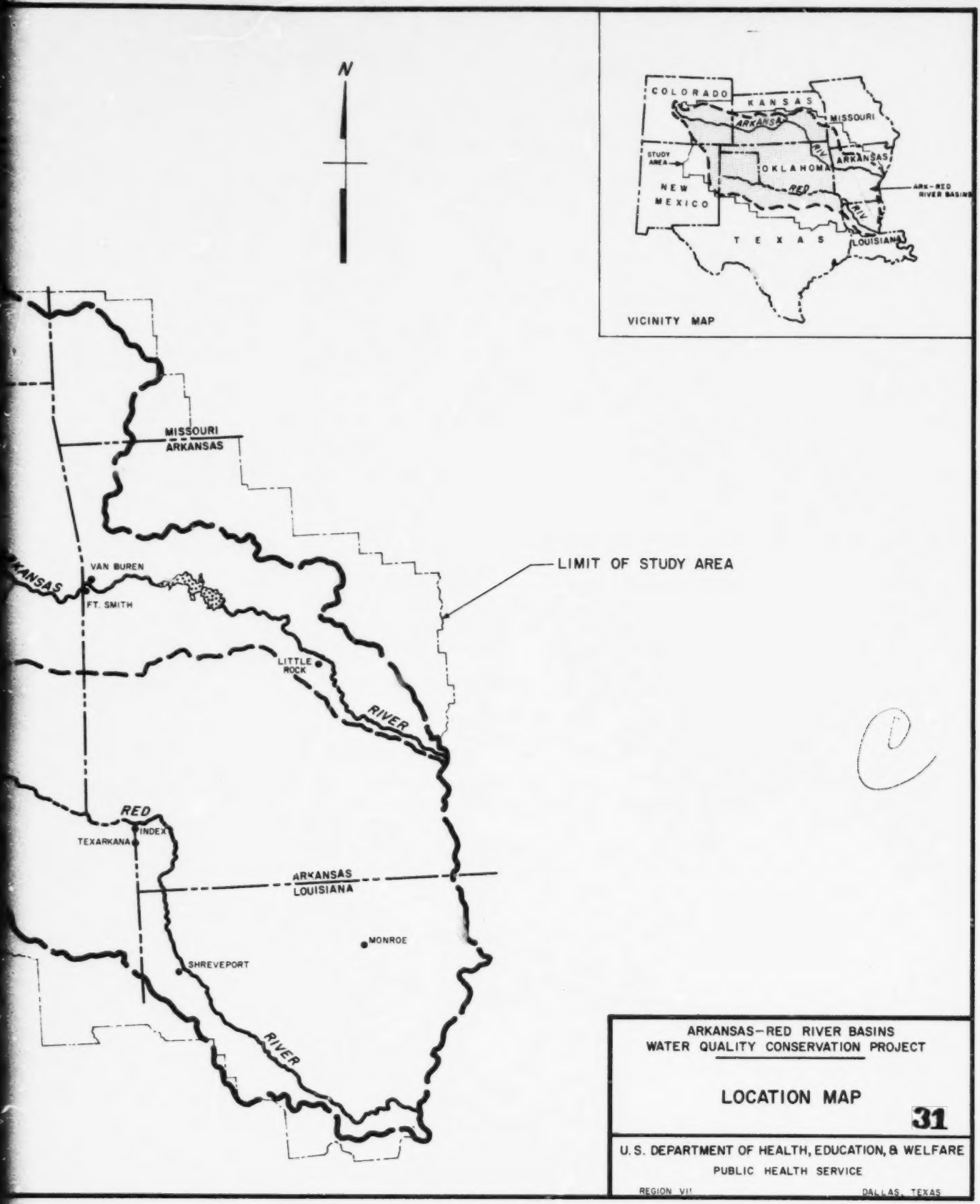
U.S. DEPARTMENT OF
PUBLIC
REGION VII



ARKANSAS–RED RIVER BASINS
WATER QUALITY CONSERVATION PROJECT

LOCATION MAP

31

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS

FIGURE 14

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Field Level Review Comments of Other Agencies

On March 16, 1964, draft copies of the Summary Report and appendixes were sent to other Federal agencies at field level and to various State agencies, having interest in the project, for review. Letters from these agencies containing their comments follow.

U. S. ARMY ENGINEER DIVISION, SOUTHWESTERN
CORPS OF ENGINEERS
1114 COMMERCE STREET
DALLAS, TEXAS 75202

IN REPLY REFER TO: SWDGA-1

8 May 1964

Mr. Jerome H. Svore
Regional Program Director
Public Health Service
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

Thank you for providing us with the opportunity of reviewing the draft of your report on "Water Quality Conservation, Arkansas-Red River Basins" dated March 1964. The comments contained herein may be accepted as the field level views of this office and of our Tulsa, Little Rock, and Fort Worth Districts. Please accept our apology for the delay in furnishing comments.

Investigations of the salt pollution of the Arkansas and Red Rivers were undertaken by the Public Health Service as authorized by the Federal Water Pollution Act. As you know, the Corps of Engineers is making an essentially companion survey of the methods for controlling natural mineral pollution in these streams pursuant to a resolution adopted 16 December 1959, by the Committee on Public Works of the U. S. Senate.

Your report delineates and describes the effects of mineral pollution in the Arkansas-Red River Basins in explicit detail. The report presentation shows that water quality along the main stem of the Arkansas River below Great Bend, Kansas and the Red River and various tributaries is seriously degraded so as to be unsuitable for most uses as a result of brine emissions and releases of sodium chloride from 15 significant sources of natural mineral pollutions in Oklahoma, Texas, and Kansas, in addition to man-made salt pollution caused by oil production.

Your service has suggested that the Corps of Engineers consider six general methods of control of pollution from the five natural brine sources in the Arkansas River Basin in Oklahoma and Kansas and from ten sources in the Red River Basin in Texas. As you know, our studies for remedial works are well advanced and we expect to submit reports during FY 1964 and 1965. Our planning has been on the basis that man-made salt pollution will be controlled to a significantly high degree.

While not stated in specific terms in water pollution control legislation (PL 84-660, as amended), those laws strongly infer that Federal policy is control of all pollution with an ultimate goal of clean streams

nation-wide. As you know, the Public Health Service report considers only water quality needs predicated on the basis of municipal and industrial and agricultural use requirements. The report also provides a monetary estimate of the value of each service by application of the conventional least alternative cost method. We have discussed on numerous occasions in coordinating our studies that use of the alternative cost doctrine may not properly indicate the true value of water quality improvement.

While we recognize the important and prime requirements of the three-use aspect of your study which include municipal, industrial, and agricultural uses, our studies are more comprehensive in character and must give consideration to all social and economic factors that may be affected by the salt problem. The merits of solutions to the salt pollution problem in these large economically developed regions is too important to the well being of its citizens to be judged solely on the three-use concept and values even though they are important. It may well be that a significant part of the merits of upgrading the Arkansas and Red River streams may have such a public character to quite properly be regarded like sewage treatment plants, highways, and schools that should be provided at the lowest possible cost in consonance with other public expenditures. Essentially, this concept is the principle on which the program for correction and control of man-made petroleum-produced salt pollution throughout the area under study is based. Economic, aesthetic and social considerations are involved in any such concept of values. While it would be highly desirable for the above considerations to be fully covered in your report, we hope that the Public Health Service will be able to help us in completing our report, particularly with respect to evaluation of the social and economic damages that may result to a large segment of the southwest if the salt problem is left unsolved.

Comments of a technical and editorial nature are attached hereto.

Sincerely yours,

E. W. FISCHER
Colonel, CE
Deputy Division Engineer

2 Incls
1. Tech. & Ed. Comments
2. 3 Sets of Report (under sep. cover)

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
AREA HYDROLOGIC ENGINEER
507 U. S. Court House
Fort Worth, Texas 76102
April 20, 1964

MEMORANDUM

TO : Mr. Jerome H. Svore
Regional Program Director
Water Supply & Pollution Control
Public Health Service
Dept. of Health, Education & Welfare
1114 Commerce Street, Dallas, Texas 75202

FROM : R. J. MacConnell
Area Hydrologic Engineer
Weather Bureau Office

With reference to your letter of March 16, 1964 transmitting the draft of the Public Health Service report on "Water Quality Conservation, Arkansas-Red River Basins", consisting of a Summary Report and a three-volume Appendix, the draft of the report is being returned with the following comment:

Your staff people have contacted this office several times during the course of the preparation of this document and the various offices of the Weather Bureau in the southwest have furnished your staff with pertinent climatological and hydrologic information required for the report.

I have been advised by the Acting Director, Office of Hydrology, Weather Bureau, Department of Commerce, Washington, D. C., that the formal review of this document will be handled at Washington level in a manner similar to the reports from the Corps of Engineers and other federal agencies. Therefore, we will appreciate your considering this in forwarding the document to higher authorities.

The seven-volume report is being returned under separate cover.

Richard J. MacConnell

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
SOUTHWEST REGION
FEDERAL BUILDING, P. O. BOX 1467
MUSKOGEE, OKLAHOMA

March 27, 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply & Pollution Control
Health, Education, and Welfare
Regional Office
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

Your report on "Water Quality Conservation, Arkansas-Red River Basins" is interesting and I would like to have been associated with the study. For thirty years this June 1, I have had a professional interest in use of the waters of the Arkansas or both rivers.

Records of streamflow and water quality in the Ark-Red Basins generally do not pre-date industrial development so that one cannot compare the dissolved mineral load of the streams now with what it was before municipal and industrial wastes were discharged therein or before saline and fresh groundwaters were allowed to mix by means of wells. I suppose that there are no records early enough to reflect the natural quality of water in Oklahoma and Texas in those areas where we know that there has been pollution.

To the contrary, in Kansas there are records of the quality of water of Arkansas Basin streams about 1905 and these records are published in Geological Survey W.S. Paper 273. As I recall, the work was done by Horatio Parker. When I worked for the State of Kansas we respected that data. Possibly you know of it but it is not mentioned in your bibliography. It would reinforce your opinion that the waters of several streams, in Kansas at least, were much better before oil industrial development.

I feel that use of the words chlorides, sulfates, salt and total dissolved solids in various places may leave the casually technical reader confused at times. In instances I wonder if the term salt is used to encompass all TDS, or only chlorides, or chlorides and sulfates. It may be important where tons per day or milligrams per liter are mentioned.

I also feel a bit uneasy about using the term pollution to encompass natural mineral loads and those for which man is responsible. In some instances even the suspended sediments in streams are called pollution. This seems unfortunate because it weakens the impact of the word.

To me the effective control of natural flow of highly mineralized water seems improbable, at least to the extent of a significant decrease in the overall load of the Arkansas or Red River. On the other hand, only an aroused public and time are necessary to restore the streams and groundwater to approximately their natural state. It is too bad that quality standards for streamflow may allow one user, the first, to virtually appropriate the dilution capacity of a stream to the exclusion of others. It is also unfortunate that the economy of a community or of a region may become dependent on an industry which cannot afford to clean its effluent.

I believe that your study and report can do much to enlist support for regulatory officials at all levels of government who would like to protect or improve our waters - and of course that includes your own Public Health Service.

Your report is being returned under separate cover. One copy of the final report will serve my needs.

Sincerely yours,

Kenneth D. McCall
Regional Coordinator

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGIONAL OFFICE, REGION 7
BUILDING 46, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY
REFER TO: 7-730

APR 9 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
Department of Health, Education and Welfare
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

We have reviewed the draft of the summary of the Public Health Service Report on "Water Quality Conservation, Arkansas-Red River Basins," dated March 1964.

We appreciate the opportunity of reviewing the report and have found the context very interesting and informative. However, the area of the Arkansas River that is being considered for water quality monitoring is south and east of our Fryingpan-Arkansas Project.

In this respect, and because the problems of brine pollution on the Arkansas River as it lies within the boundaries of Region 7 are far less severe than those experienced in the lower reaches of the Arkansas River, we feel that our comments at this time could only be of cursory interest.

As of this date we have received only the draft copy of the summary of the above mentioned report and will, upon receipt of the three volume appendix,return the draft copies of both the summary and appendix to your office. We would also like one copy of the final report when it becomes available.

Again we thank you for the opportunity of reviewing your report and hope that you will find it convenient to keep us informed as to the progress and results of your proposed study.

Sincerely yours,

H. P. Dugan
Director

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

REGIONAL OFFICE, REGION 5
P. O. BOX 1609
AMARILLO, TEXAS

IN REPLY
REFER TO: 5-730

APR 24 1964

Mr. Jerome H. Svore
Regional Program Director
Department of Health, Education, and Welfare
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

This is in reply to your letter of March 16, 1964, inviting our comments on your draft report on "Water Quality Conservation, Arkansas-Red River Basins."

The consolidated comments of this office and our Albuquerque, New Mexico; Austin, Texas; and Oklahoma City, Oklahoma, Development Offices are as follows:

The report contains very good factual data concerning the source and concentrations of chlorides, sulphates, and dissolved solids in the Arkansas and Red River Basins. However, the benefits shown are based on an assumed degree of control which has not been demonstrated. It would seem more reasonable if the report were limited to factual pollution data, and the benefits to be expected were related to specific control works to be devised by the Corps of Engineers for each specific location.

Municipal water requirements are estimated by projecting populations for 82 subareas and multiplying these figures by a projected (2010) per capita use figure for each subarea. A comparison between population and water requirements forecasts made in your report and forecasts prepared for the Bureau of Reclamation by the Oklahoma University Bureau of Business Research 1/ for the Oklahoma City area is shown below. The wide differences are apparent.

1/ "An Analysis of Economic Potential and Water Requirements of North Central Oklahoma", made for the Bureau under contract dated 1953.

Agency	Area Included	Forecast Population	Forecast Water Demand (mgd)	Forecast Year
PHS	Oklahoma, Canadian & Cleveland Counties	1,820,000	315	2020
Bureau of Business Research	Oklahoma, Canadian, Cleveland, Payne, Logan, Lincoln, Blaine, McLain & Kingfisher Counties	839,800	143	2010

The value of municipal and industrial water supply benefits is taken as the combined cost of storage, transmission and treatment of water from the most likely alternative source, less the total cost of obtaining water from reaches of the streams that will be affected by water quality improvement. In the sample computation given in the report for the Oklahoma City area, the alternative source is the Tuskahoma Reservoir site on the Kiamichi River in southeastern Oklahoma. With quality improvement, the source used is the Keystone Reservoir on the Arkansas River near Tulsa. This demonstrates our earlier point that benefits are based on a degree of quality control that has not been demonstrated. We seriously doubt that the quality of Keystone water can be improved sufficiently for municipal use.

Additional discussion of the method used to determine industrial water supply benefits would be helpful. Industrial water requirements include petrochemical and other developments in the areas apparently without consideration of alternative locations for these industries outside of the areas studied. The report implies that as soon as costs are available from the Corps of Engineers, construction of works to control natural salt emission at the 15 major sources identified should be undertaken. The Water Pollution Control Act, as amended, advances that in those cases where the beneficiaries can be identified and are local in scope, the costs associated with water quality control will be reimbursable. Such cases should require that a repayment contract be negotiated or assured prior to the initiation of construction. It seems that each of the 15 projects reported on would present individual problems which would require individual treatment.

The dryland crop production and the irrigation land use, water requirements and yields appear to be reasonable. However, the derivation of the irrigated acreage requirements for 2020 could be more clearly stated.

The following specific comments, relative to Appendix Volume III, are suggested for your consideration in further processing of the report:

Figure 1-1, Study Area Details - Several reservoirs in the study area, such as Ute Reservoir (New Mexico), Altus Reservoir (Oklahoma), and Norman Reservoir (Oklahoma), are not indicated on the map.

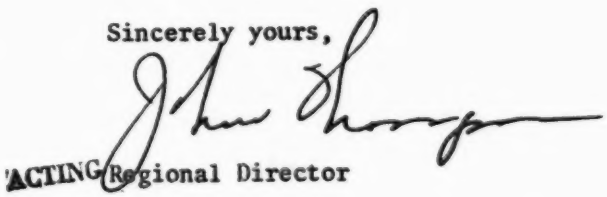
Table IV-1, page IV-3 - The table shows Norman Reservoir as a committed source for municipal and industrial water requirements for Oklahoma City. The Norman Project, when completed, will supply water for the cities of Norman, Del City, and Midwest City. Oklahoma City is not participating in the project.

Table IV-1, page IV-4 - The table should indicate Sanford Reservoir as a committed source of water supply for the city of Plainview, Texas. Plainview is one of 11 cities which will receive water from Sanford Reservoir. Also, the word "Texarkans" in footnote g should be "Texarkana."

The report draft is being returned under separate cover. Please furnish this office and our Oklahoma City Development Office a copy of your final report when it is available for distribution.

Your courtesy in furnishing us an opportunity to review the report is appreciated.

Sincerely yours,



ACTING Regional Director

Separate Cover (35704)
Draft report on "Water Quality Conservation, Arkansas-Red River Basins."

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

[redacted]
AREA IV
MINERAL RESOURCE OFFICE

ROOM 206 FEDERAL BUILDING
BARTLESVILLE, OKLAHOMA

OFFICE OF
[redacted]
AREA DIRECTOR

April 24, 1964

Department of Health, Education and Welfare
Regional Office
1114 Commerce Street
Dallas, Texas 75202

Attention: Jerome H. Svore, Regional Program Director, Water Supply & Pollution Control

Dear Sir:

We have reviewed the draft of the Public Health Service report on "Water Quality Conservation, Arkansas-Red River Basins", consisting of a Summary Report and a three-volume Appendix.

The study area encompasses all of the Arkansas and Red River Basins plus minor adjoining portions of the Missouri, White, Trinity, Brazos, and Sabine River Basins. This area consists of a total of 327 counties in Oklahoma, Colorado, New Mexico, Kansas, Texas, Missouri, Arkansas, and Louisiana, and represents approximately 9 percent of the land area and 5 percent of the population of continental United States.

The study area includes all counties partly or entirely within the Arkansas-Red River Basins, together with those adjoining counties which are expected to be directly affected by an improvement in the water quality of the mineral-polluted streams.

The objectives of the project were:

1. To locate and define the significant natural and manmade sources of salt (mineral) pollution.

2. To determine the effects of these sources on the quality of water in the receiving streams.

3. To propose possible methods and procedures for reduction of these highly mineralized discharges.

4. To estimate the results of reduction of these discharges on stream quality.

5. To determine the benefits of water quality improvements to present and future municipal, industrial, and agricultural water users.

The natural brines come from individual large springs, numerous small seeps, large marshes, or salt-encrusted flats. Fifteen significant sources of natural mineral pollution, five in the Arkansas and ten in the Red River Basin, have been located and identified as the primary causes of water quality deterioration with respect to minerals. Nine additional natural salt sources have been located and classified as of secondary importance.

Brines entering the basins' waters resulting from man's activities are largely the consequence of petroleum and natural gas production. Yet, over 95 percent of the brines produced as a result of petroleum and natural gas extraction activities within the Arkansas-Red River Basins is reinjected into the producing strata for secondary petroleum recovery and/or pollution abatement.

Some streams, such as the Cimarron River in Oklahoma and the Wichita River in Texas, are polluted primarily by natural brines; other streams, mainly those of the Canadian River system outside the natural brine producing area, appear to be polluted only by manmade wastes.

Reduction of mineral pollution by control of the significant natural pollution sources located and defined by this study together with adequate control of manmade sources of mineral pollution will result in water of quality suitable for general municipal, industrial, and agricultural use through nearly all of the basins.

If the water quality of the two-river system is improved sufficiently to meet future water requirements, the average annual value of the benefits, over the 50-year period between 1970 and 2020, will be $9.2 million. Value of the benefits, when spread over the 100-year period between 1970 and 2070, will amount to $13.1 million annually.

The findings of the Arkansas-Red River Basins Water Quality Conservation Project have provided a basis for considering control of salt pollution in the two rivers. In accordance with these findings, the following 4-point program is recommended for approval and implementation as rapidly as legislative authority and appropriation permit.

1. As soon as the U. S. Army Engineers' designs and costs are available, engineering works should be considered for construction to control natural salt emission at the 15 major sources identified in this report. First priority should be given to three tributaries of the Wichita River, Elm Fork of the Red River, Estelline Spring, and Jonah Creek in Texas, and the Big and Little Salt Plains on the Cimarron River together with the Great Salt Plains on the Salt Fork of the Arkansas River in Oklahoma.

2. The State and the Federal governments should continue and strengthen their efforts to reduce salt pollution arising from oilfields and other mining and industrial operations, using when appropriate and necessary the enforcement provisions of the Federal Water Pollution Control Act.

3. The Public Health Service should immediately institute a continuous and, where possible, automatic system of water pollution monitoring in the two river basins. Such a system would provide intelligence on water quality in the streams, essential to the efficient operation of those structures which are or may be built in the two basins for quality control. Headquarters for the monitoring and data interpretation would be located at the new regional water pollution control laboratory being built at Ada, Oklahoma.

4. The Basin States and the Federal Government should develop a permanent program of mutually acceptable procedures to minimize the adverse effects of salt pollution at points of water use in the two river basins.

Our comments on the report are all favorable. Your analysis of the pollution problems in the basins and recommendations for minimizing the future problems are logical and well supported. Because of the economic importance of the oil and gas industry to the study area, we are vitally interested in its role in the situation.

We are returning, under separate cover, the draft copy and would appreciate receiving one copy of the final report.

Sincerely yours,

Robert S. Sanford

Robert S. Sanford
Area Director

Separate cover:
Draft "Water Quality Conservation, Arkansas-Red River Basins"

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE

P. O. BOX 1306
ALBUQUERQUE, NEW MEXICO

April 21, 1964

AIRMAIL

Mr. Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
Department of Health, Education, and Welfare
1114 Commerce Street
Dallas, Texas

Dear Mr. Svore:

This is in response to your letters to the Supervisor, Office of River Basin Studies, Fish and Wildlife Service, Tulsa, Oklahoma, and to this office, dated March 16, 1964, transmitting for our review and comments a draft of your report on "Water Quality Conservation, Arkansas-Red River Basins."

We appreciate the opportunity to review these documents and to explain that we are participating in the study to the extent of conducting cooperative studies with the appropriate state wildlife departments and with the Corps of Engineers on the effects of the proposed developments on fish and wildlife resources.

The Bureau of Sport Fisheries and Wildlife conducts investigations under the authority of the Fish and Wildlife Coordination Act to determine effects on fish and wildlife resources of water-resource development projects planned and constructed with Federal funds and under Federal permit or license, and recommends measures for the protection and improvement of these resources. Our reports on the Water Quality Conservation Project will be based on plans of development proposed by the Corps of Engineers for each area and will contain an estimation of benefits or losses attributable to the project. Our report also will present recommendations for enhancement of fishing and hunting and, when necessary, for mitigation of losses to fish and wildlife.

It is our plan to complete fish and wildlife studies on all of the water quality areas by February 15, 1965, in order that our reports will be available to accompany those of the Corps of Engineers. To date, we have completed fish and wildlife reports on Areas I, II, III, IV, VII, VIII, X, and XV.

765-197 O - 65 - 4

Some of the water quality areas, where the proposed plan of development includes establishment of freshwater reservoirs, will provide a significant number of man-days of reservoir-type sport fishing and a potential for a moderate quality commercial fishery. However, it is estimated that the chloride content of the permanent waters impounded in the brine evaporation reservoirs will exceed the maximum tolerance of freshwater fishes. Introduction of saltwater fishes is thought to be infeasible at this time.

The Water Quality Conservation Project is expected to reduce significantly the natural chloride pollution of the Arkansas and Red Rivers and the reservoirs thereon, and, theoretically, should improve fish habitat. However, the reduced chloride content is expected to result in increased turbidity in the freshwater reservoirs and in the streams downstream from the projects. The adverse effect of increased turbidity on fish habitat, plus reduced streamflows anticipated with the projects will tend to nullify the beneficial effects of chloride reduction.

Fish species composition, especially in the streams, is expected to be altered by the reduction in chloride concentration. Minnow populations presently of high commercial value, will be reduced. Conversely, sport fishes in some instances will find the lower saline waters more conducive to increased production. However, the reduction or possible loss of commercial minnow populations is of far greater importance to the economy of the area than the potential increase of sport fishing that may be attributed to the project.

Some of the project impoundments will be moderately beneficial to migratory waterfowl. Upland-game and big-game habitat will be lost as a result of the projects and should be compensated for by the establishment of wildlife management areas in conjunction with the individual projects when feasible.

We are returning our review copy of your Summary Report and the three-volume Appendix under separate cover. Mr. Forrest S. Romero, Supervisor of our Branch of River Basins Studies Field Office in Tulsa wishes to retain the copies sent to him for reference until the final draft is ready for release, at which time changes may be forwarded to him for insertion, or the report exchanged for a new one.

Incidentally, please note that the address of Mr. Romero's office is now:

Mr. Forrest S. Romero, Field Supervisor
Branch of River Basin Studies
Bureau of Sport Fisheries and Wildlife
923 Petroleum Building
420 South Boulder
P. O. Drawer 1619
Tulsa, Oklahoma 74101

Sincerely yours,

John C. Gatlin
Regional Director

Under separate cover:
Report and three-volume appendix

cc:
District Engineer, Corps of Engineers, U. S. Army, Tulsa, Oklahoma
Director, Kansas Forestry, Fish and Game Commission, Pratt, Kansas
Director, Oklahoma Department of Wildlife Conservation, Oklahoma City, Oklahoma
Executive Director, Texas Parks and Wildlife Department, Austin, Texas
Field Supervisor, Branch of River Basin Studies, Bureau of Sport Fisheries and Wildlife, Tulsa, Oklahoma

IN REPLY REFER TO
Water Resources Division

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
FEDERAL CENTER DENVER 2 COLORADO

May 1, 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply & Pollution Control
U. S. Public Health Service
Dallas, Texas 75202

Dear Mr. Svore:

Attached are our comments on the report "Water Quality Conservation, Arkansas-Red River Basins." These represent a consolidation of comments from the several offices of the Geological Survey to which copies of the report were sent for review.

The report contains a wealth of basic data and develops an excellent factual picture of the problems involved because of the salt contamination of the region's water supplies. We have limited our comments to the basic-data aspects of the report and have not attempted to evaluate the probable efficacy of the proposed remedial measures.

As I believe you are aware, we are engaged in further studies of the factors that control the occurrence of brine discharge in the Permian Basin area. At the present time, our studies are concentrated in the upper Brazos River Basin in Texas. Progress on these studies has been hampered somewhat by a delay in test-drilling operations, but we hope to have something to report early in the 1965 fiscal year. We will be glad to furnish you results of these investigations as they become available. Our studies and analyses to date indicate that the controls may be of a regional nature, rather than strictly local as indicated in prior studies.

We are returning the review draft of the Summary Report and the three-volume Appendix under separate cover. Copies of the final report should be furnished to the following offices of the Geological Survey:

S. K. Jackson, Division Hydrologist, Denver, Colorado

C. H. Hembree, District Geologist, Quality of Water Branch, Austin, Texas

E. J. Kennedy, District Engineer, Surface Water Branch, Topeka, Kansas

A. A. Fischback, Jr., District Engineer, Surface Water Branch, Oklahoma City, Oklahoma

We appreciate the opportunity to review the report and comment on it and will follow the results of this comprehensive and significant study with great interest.

Sincerely yours,

S. K. Jackson
Division Hydrologist

Enclosure

cc:
Trigg Twichell
Austin, Texas

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Southwest Region
Santa Fe, New Mexico

IN REPLY REFER TO:

L7423

MAR 24 1964

Mr. Jerome H. Svore
Regional Program Director
Department of Health, Education,
and Welfare
1114 Commerce Street
Dallas, Texas 75202

Dear Sir:

Thank you for the opportunity of reviewing the draft of your report on "Water Quality Conservation, Arkansas-Red River Basins". We are quite interested in your general study objectives and in the findings and recommendations given in your Summary Report.

Neither any of our Service areas nor reservoir proposals on which we are making cooperative studies are in the affected streams vicinity of your particular study. However, we would appreciate one copy of the final Summary Report. The three-volume Appendix will not be needed.

All of the draft copies sent us for field level review are returned under separate cover, identified by a copy of this letter.

Sincerely yours,

Norman B. Herkenham

Norman B. Herkenham
Acting Assistant Regional Director,
Cooperative Activities

Separate cover:
1 Summary Report /
3 Volume Appendix/ (7 books)

IN REPLY REFER TO:
SPA-RH

UNITED STATES
DEPARTMENT OF THE INTERIOR
SOUTHWESTERN POWER ADMINISTRATION
POST OFFICE DRAWER 1619
TULSA 1, OKLAHOMA

April 16, 1964

Regional Program Director
Water Supply & Pollution Control
Department of Health, Education, and Welfare
1114 Commerce Street
Dallas, Texas 75202

Dear Sir:

This letter is in reply to your letter of March 16, 1964, requesting a field level review of your report on Water Quality Conservation, Arkansas-Red River Basins. Since no specific engineering projects are proposed which will affect stream flows, nothing in the report will affect the interests of this Administration. As requested, our draft copy of the report is being returned.

Sincerely yours,

Carl E. Roberts
Chief, Division of Planning and
Resources

Enclosure
(Separate Cover)
Water Quality Conservation Arkansas-Red
River Basins Summary, Appendix Vol. I,
Vol. II Part 1 thru Part 5, Vol. III.

FEDERAL POWER COMMISSION
REGIONAL OFFICE

100 North University Drive
Fort Worth, Texas 76107
March 25, 1964

Regional Program Director
Department of Health, Education, and Welfare
Regional Office, Dallas
1114 Commerce Street
Dallas, Texas 75202

Dear Sir:

Receipt is acknowledged of your letter dated March 16, 1964 transmitting a draft copy of the Public Health Service report on "Water Quality Conservation, Arkansas-Red River Basins", consisting of a Summary Report and a three volume Appendix for field level review and comment. The report is impressive in its thoroughness and in the clarity of presentation of data.

We have an interest in all water resource developments, however, our primary interest is in the effect that proposed improvements will have on both existing and potential hydroelectric power developments. Accordingly, we are more interested in the quantity of water that would be consumed, if any, as a result of the proposed program than in the quality control measures.

We appreciate the opportunity to review the report and to submit comments which are prepared at field level and should not be construed as those of the Federal Power Commission.

As requested in your letter, the Summary Report is being returned herewith. This office would appreciate receipt of a copy of the Summary Report in final form. The seven books which make up the three volume Appendix to the Summary Report are being returned under separate cover.

Sincerely yours,

Lenard B. Young

Lenard B. Young
Regional Engineer

Enclosure No. 4118:
Summary Report
Enclosure No. 4119:
Appendix (u.s.c.)

J. T. HERRON, M. D.
STATE HEALTH OFFICER

ARKANSAS
STATE BOARD OF HEALTH

LITTLE ROCK

April 28, 1964

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E. D. McKNIGHT, M.D. . . . . Brinkley
ANGIE FAYE WALDRUM, R.N. . . . . Little Rock

Department of Health, Education, and Welfare
Regional Office
1114 Commerce Street
Dallas, Texas

Attention: Jerome H. Svore
Regional Program Director
Water Supply & Pollution Control

Dear Mr. Svore:

Due to insufficient time between the receipt of the report and the deadline set by your office for receipt of comments, this office has not completed its review. We, therefore, rather than offer comments based on an incomplete analysis, offer no comments.

The review draft is being returned as requested.

Yours very truly,

BUREAU OF SANITARY ENGINEERING

G. T. Kellogg
Chief Sanitary Engineer

GTK:bb

ARKANSAS WATER POLLUTION CONTROL COMMISSION

921 WEST MARKHAM
LITTLE ROCK 72201

April 23, 1964

Mr. Jerome Svore, Regional Program Director
Water Supply & Pollution Control
Public Health Service
Regional Office VII
1114 Commerce Street
Dallas 2, Texas 75202

Dear Mr. Svore:

We are returning the Summary Report and Appendix of "Water Quality Conservation, Ark-Red River Basins" under seperate cover. A comparison of the three year record in the subject study with our 15 year record analysis (U. of Ark. research project) indicates very close correlation.

Ark. at Van Buren

	Equation		Corr. Coefficient	
	PHS	U. of A.	PHS	U. of A.
Cl^-	0.26846SC-52	.3020SC-85.7	0.9830	0.993

Red at Fulton

Cl^-	0.2195SC-43	.1970SC-19.4	0.9922	0.994

Very truly yours,

M. L. Wood, Director

MLW:gb
Enclosures

STATE OF COLORADO DEPARTMENT OF PUBLIC HEALTH
4210 EAST 11TH AVENUE · DENVER 20, COLORADO · PHONE DUdley 8-5801
R. L. CLEERE, M.D., M.P.H., DIRECTOR

April 20, 1964

Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
Public Health Service
551 First National Bank Building
Denver, Colorado

Dear Mr. Svore:

We have reviewed the draft of the Public Health Service report on "Water Quality Conservation, Arkansas-Red River Basins".

We do not have any suggestions for changes in this Report.

Very truly yours,

FOR DIRECTOR, ENGINEERING & SANITATION DIVISION

George A. Prince

George A. Prince, P.E., Chief
Public Health Engineering Section

cc: Fred Matter, District Engineer
Wm. N. Gahr
GAP:dp

765-197 O - 65 - 5

57

THE KANSAS STATE BOARD OF HEALTH

TOPEKA
KANSAS

Division of Environmental Health Services

April 28, 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
U.S. Public Health Service
1114 Commerce Street
Dallas, Texas 75202

Dear Jerry,

I regret we have not yet been able to complete our review of the Public Health Service report on "Water Quality Conservation, Arkansas - Red River Basins". The report is quite extensive and preliminary appraisals indicate it is worthy of more than cursory review.

Our present schedule indicates we will have our review and comments completed on or before 15 May, 1964. If you arrange for a meeting with the Kansas Water Resources Board to discuss the report, perhaps we can meet with you the same day.

ENVIRONMENTAL HEALTH SERVICES

J. Lee Mayes

J. Lee Mayes
Chief Engineer & Director

JLM:sk

THE STATE OF KANSAS

WATER RESOURCES BOARD
1134-S STATE OFFICE BUILDING
Phone CE 5-0011, Extension 695
TOPEKA

May 18, 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
U. S. Public Health Service
1114 Commerce Street
Dallas 2, Texas 75202

Dear Jerry:

My letter of April 22, 1964, indicated that the Kansas Water Resources Board would have some comments on the reports entitled "Water Quality Conservation, Arkansas-Red River Basins" that were submitted for our review. This report provides a valued service in analyzing and describing the problems of mineral water quality in the two major river basins. We are in agreement with the mineral pollution problem in the basins as is generally described in the report. By compiling, assembling, and publishing quality data for the entire basins, and by identifying and evaluating the major mineral pollution sources, this study sets a landmark for which you will long be remembered.

The major comments by the Kansas Water Resources Board on the report are attached. Listed separately are general comments on "Volume I" and the "Summary Report". The major points are discussed in more detail.

The above comments refer to items that we believe would benefit the report. Although we did not review the reports with the intent of marking all little mistakes or oversights, comments on some are noted in blue within the texts of the reports in the set that is being forwarded under separate cover.

We have not made an extensive evaluation of the bibliographies. However, we do have some reservations on the support value of some of them. Two examples are:

1. In Table VIII-1 of the Summary Report, the 1952 edition (evidently meaning the 1957 edition) of the California "Water Quality Criteria" is listed as support for a suggested chloride concentration of 30 mg/l for the dairy industry. We can find no reference to dairy standards in the 1957 edition. The 1963 edition lists 30 mg/l as a dairy standard referred to by an European author. No doubt, the author had some particular purpose in mind. However, this has little bearing to the dairy industry in the Arkansas-Red basins which has long thrived on waters containing many times 30 mg/l of chlorides.

2. The first paragraph on page II-23 of "Volume III" lists the 1957 edition of the California "Water Quality Standards" as a reference that . . . drinking water of good quality may contain up to 115 mg/l of sodium, but a limit of 10 mg/l is usually recommended as desirable.

   I know that I needn't emphasize that the above statement is in error. The California "WQS" (the 1957, as well as the current edition) lists a 1934 reference by Hibbard for the statement. Hibbard actually did not even suggest such a sodium limit for drinking waters. He did suggest some standards for washing waters and pottery making, from which the 10 ppm came, but which in itself was incorrectly interpreted.

We believe that it is important to keep the physical development of any resources program in step with the needs. This points out the value of advanced planning such as is represented in the reports. However, it also points out that a long-range program shouldn't be constructed in a short span of time, as it would place too much of a burden on local governments and states, as well as the federal government.

While the enclosed comments will indicate that we differ on some aspects of philosophy and recommendations, as stated initially, we wholly agree as to the purpose of this study and we appreciate the time and effort that it has entailed. If there is any doubt concerning the validity of any of our comments, we would like an opportunity to discuss them. Would you also inform us as to how the report will be handled from now on, and to whom it is to be submitted?

Very truly yours,

Dwight F. Metzler

Dwight F. Metzler
Executive Secretary

DFM:ss

cc: State Department of Health

State of Louisiana

CLAUDE KIRKPATRICK
DIRECTOR

DEPARTMENT OF PUBLIC WORKS
BATON ROUGE 4

April 17, 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply & Pollution Control
Department of Health, Education, and Welfare
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

Reference is made to your letter of March 16, 1964, transmitting a copy of the U.S. Public Health Service Summary Report and three-volume Appendix on "Water Quality Conservation, Arkansas-Red River Basins" for our review and comments.

After reviewing the report, we would like to submit the following comments:

A coordinated effort should be made to expedite the construction of recommended engineering works to control natural salt emission at the fifteen major sources identified in the report.

Any recommended plan for transferring or diverting good quality water from one basin to another to improve the quality should be deferred until completion of the Red River Compact negotiations.

On basis of records for stations in Louisiana at Hosston, near Louisiana-Arkansas State Line, and at Alexandria during the 1961 and 1962 water years, the chloride concentrations were more than 250 p.p.m. and less than 400 p.p.m. for about 100 days.

It is recommended that the man-made and natural salt pollution be eliminated or materially reduced in the Arkansas-Red River Basins.

We would like to have ten (10) copies of the final report when it becomes available.

Your courtesy in inviting our comments on the report is greatly appreciated.

Sincerely yours,

Claude Kirkpatrick

CLAUDE KIPKPATRICK
Director

/an

STATE OF LOUISIANA
STREAM CONTROL COMMISSION
P. O. Box 9055, University Station
BATON ROUGE 3, LOUISIANA

May 21, 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
Public Health Service
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

I have reviewed the draft of the Public Health Service report on "Water Quality Conservation, Arkansas-Red River Basins." The Summary Report I reviewed rather closely; the three-volume Appendix was scanned only within the limits of my physical capacity to review such a vast selection of data.

My only comment is most ably worded on Page VIII-2 of the Summary Report from which I quote verbatim: "Local and state officials have indicated that mineral concentrations should be reduced as much as possible to afford maximum development opportunities to industries requiring high quality water. The ultimate objective is a reduction in the salt loads of the entire river system. This should encourage economical development uniformly throughout the basin, other factors being equal."

Under separate cover I am returning the Summary Report and the three-volume Appendix as requested.

Thanking you for availing me the opportunity of reviewing this mass of data, I am

Yours very truly,

Robert A. Lafleur
Executive Secretary

RAL/fbr

DR. LLOYD E. CHURCH, Chairman
Wilburton, Oklahoma

OKLAHOMA WATER RESOURCES BOARD

STATE CAPITOL
OKLAHOMA CITY, OKLAHOMA
FRANK RAAB, Executive Director

May 13, 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply & Pollution Control
Department of Health, Education, and Welfare
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore: Attention Mr. Klyde Z. Huston

In compliance with your letter of March 16, 1964, we have reviewed the draft of your department on "Water Quality Conservation, Arkansas-Red River Basins" consisting of a Summary Report and a three-volume Appendix.

This report is made on behalf of the Oklahoma Water Resources Board, and as Chairman of the State Agencies Coordinating Committee on Land and Water Resources Project Development. Your report is very comprehensive and the problem of pollution abatement both of man made and natural pollution is, of course, of great concern to us all. We believe that your recommendations contained in the report will greatly reduce the existing problem, and the physical works necessary should be undertaken just as quickly as possible.

The State of Oklahoma, as you know, through its State Agencies Coordinating Committee, is making a diligent effort and is making substantial progress in reducing the contribution to man made pollution in the basins covered in your report.

While some of the projects recommended in the report are under active consideration by the Corps of Engineers and the design of physical works to control the areas in which natural pollution is a major problem, to this effort the State of Oklahoma pledges its full cooperation. Therefore, we concur generally in your report.

As suggested by you, we are returning, under separate cover, the review draft of the Summary Report and the three-volume Appendix. We will appreciate receiving 12 copies of the final report for distribution to our interested state agencies and members of our Board.

Respectfully submitted,

Frank Raab
Executive Director
OKLAHOMA WATER RESOURCES BOARD

FR:lt
cc: Colonel John W. Morris
Corps of Engineers, Tulsa, Oklahoma

GLADE R. KIRKPATRICK, Vice Chairman, Tulsa, Oklahoma
GEO. R. BENZ, Secretary, Bartlesville, Oklahoma
GUY H. JAMES, Oklahoma City, Oklahoma
JOHN R. CURRY, Antlers, Oklahoma
L. L. MALES, Cheyenne, Oklahoma
JOE SYKORA, Stroud, Oklahoma

Texas State Department of Health

JAMES E. PEAVY, M.D., M.P.H.
COMMISSIONER OF HEALTH

J. B. COPELAND, M.D.
DEPUTY COMMISSIONER

AUSTIN, TEXAS

May 12, 1964

BOARD OF HEALTH

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I. O. FLORES, JR., B.S. PHAR.
JOHN M. SMITH, JR., M.D.

Richard F. Boyd, M. D.
Regional Health Director
Department of Health, Education and Welfare
Public Health Service - Region VII
Ninth Floor - 1114 Commerce Street
Dallas, Texas

ATTN: Mr. Klyde Huston

Dear Doctor Boyd:

This is to confirm the telephone conversation of this morning between our Director, Mr. D. F. Smallhorst, and your office commenting on your "Summary Report" and Volumes I, II, and III on the Arkansas-Red River Basins.

As commented, we are in general accord with the material submitted and wish to congratulate your office on a tedious job well done. We might remind you of one slight oversight which could easily be corrected in the final report, in that our associated pollution control agency is correctly designated as the "Texas Water Pollution Control Board" and not as the "Water Pollution Commission".

We plan to keep the preliminary reports in our files, pending receipt of the final version, at which time we will destroy the ones we now have.

Very truly yours,

NEDavis

N. E. Davis, Chief Engineer
Field Investigations
Division of Water Pollution Control

NED:go

TEXAS WATER COMMISSION

COMMISSIONERS

JOE D. CARTER, CHAIRMAN
O. F. DENT
H. A. BECKWITH

813 STATE OFFICE BUILDING
201 EAST 14TH STREET

AREA CODE 512
GREENWOOD 6-6791

P. O. BOX 2311
CAPITOL STATION
AUSTIN 11, TEXAS

JOHN J. VANDERTULIP
CHIEF ENGINEER

C. R. BASKIN
ASS'T. CHIEF ENGINEER

ROGER TYLER
CHIEF EXAMINER

AUDREY STRANDTMAN
SECRETARY

May 11, 1964

Mr. Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
Public Health Service
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

The draft of the Public Health Service Report on "Water Quality Conservation, Arkansas-Red River Basins", consisting of a summary report and a three-volume appendix has been received for field level review. Notice is also taken that the transmitted copy of the review draft is not for public release.

Your agency is to be commended for the scope of the investigation undertaken and the publication of the report and accompanying data.

Our agency appreciates the opportunity to have reviewed the report.

Yours very truly,

John J. Vandertulip
Chief Engineer

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